Chapter 4:

Results and Discussion

Results and Discussion

According to the results of the chemical analysis of the water samples collected from the Nile River, Ismailia canal and the drains in Qalubia Governorate, the following results could be outlined:

4.1 Physicochemical Parameters

4.1.1 pH

The pH is a measure of the acid balance of a solution but is seldom a problem by itself. The main use of pH in a water analysis is for detecting abnormal water. The pH of natural waters has major consequences for the organisms that live there. Acidification is a particular problem, because more human inputs into natural systems are acidic than basic. A decrease in the pH much below the neutral value of 7.0 can result in a variety of effects on lakes, rivers, and streams and their inhabitants (71).

pH values are presented in Appendix A, Table I, for the Nile River water ranging from 7.27 at El-Ameria water treatment plant (sample No. A8), to 8.30 at Shoubra power station discharge (sample No. A2).

For the drains water samples, pH values are outlined in Appendix A, Table II, range between 7.12 at Shebeen El-Kanater drain before Kafer Hamza drain (sample No. B5) and 8.01 at El-Qalubia drain after Eskander drain discharge (sample No. B13).

All pH values for the River Nile water samples and the drains are within the recommended limits of Egyptian standards (Law 48/1982).

Decrease in the pH values of drains water compared to the River Nile water may be due to that these drains contain large quantities of organic matter that get oxidized by bacterial decomposition. Certain bacteria in the presence of atmospheric oxygen and water oxidize the sulfur present in these drains. Also, pH values at industrial drains were higher than sewage drains (72-74).

4.1.2 Electrical Conductivity (EC)

Electrical Conductivity, or specific conductance, is a measure of the ability of water to conduct an electric current. Conductivity is expressed as microsiemens per centimeter (µS/cm) and, for given water body, it is related to the concentrations of total dissolved solids and major ions.

The conductivity of most fresh water ranges from 10 to 1000 µS/cm but may exceed 1000 µS/cm, especially in polluted waters, or those receiving large quantities of land run-off (9).

EC values are presented in Appendix A, Table I, and are illustrated in Fig. 4.1 for the Nile River water samples range from 320 µS/cm in Ismailia canal at the front of Decorama company (sample No. A6) and 440 µS/cm at El-Kahera for oil refining company (sample No. A11).

For drains water samples, EC values are presented in Appendix A, Table II, and are illustrated in Fig. 4.2 range from 1130 µS/cm at El-Qalubia drain before mixing with Shebeen El-Kanater drain (sample No.B15) and 1520 µS/cm at Shebeen El-Kanater drain (sample No. B2).

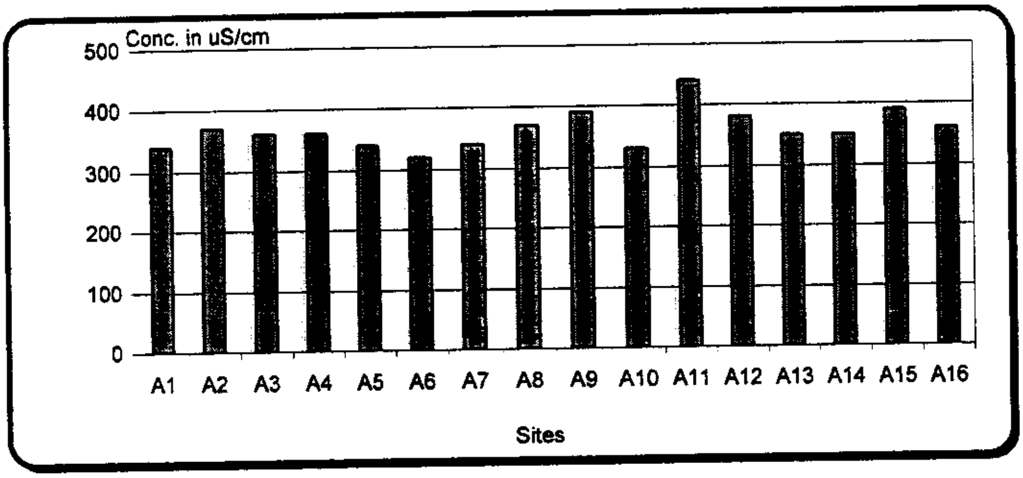


Fig. 4.1, Distribution of EC in the Nile River water samples

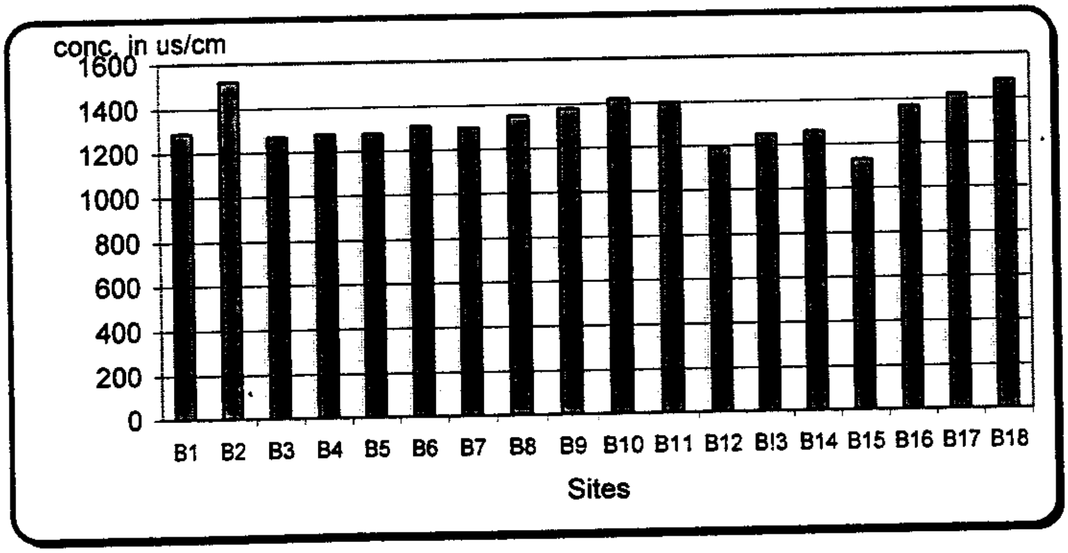


Fig. 4.2, Distribution of EC in the drains water samples

The increase in EC values for drains water reflects the increase in soluble cations and anions, which were produced from the activities in the area under study.

4.1.3 Total Dissolved Solids (TDS)

The total dissolved solids (TDS) is The total amount of dissolved chemicals species in water. It is a good general measure of the concentration of ionic substances in water. In general, fresh water has less than 1500 mg/l of TDS, brackish water between 1500 and 5000 mg/L TDS, and saline water abave 5000 mg/L (75,76).

TDS values are outlined in Appendix A, Table I, and are illustrated in Fig. 4.3 for the Nile River water samples ranging from 187 mg/L in Ismailia canal at the front of Decorama company (sample No. A6) to 263 mg/L at El-Kahera for oil refining company (sample No. A11). From these results TDS Concentrations in the river Nile water are within the permissible limits of law 48 (500 mg/L).

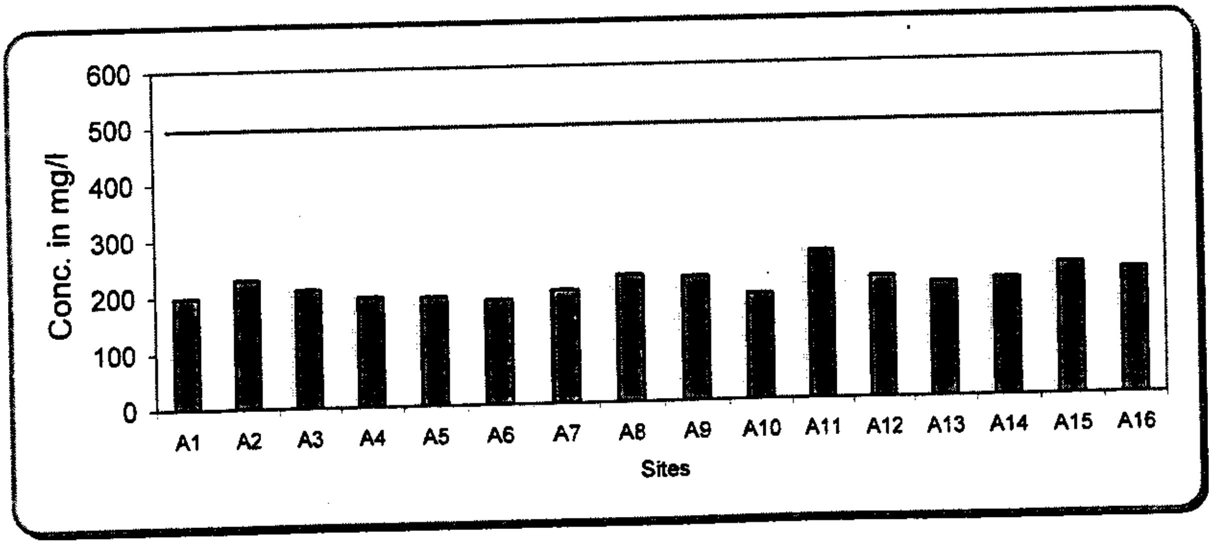


Fig. 4.3, distribution of TDS in the Nile River water samples

On the other hand, in drains water samples, TDS values, which are outlined in Appendix A, Table II, and are illustrated in Fig. 4.4 range from 687 mg/L at El-Qalubia drain before mixing with Shebeen El-Kanater drain (sample No.B15) to 941 mg/L at Shebeen El-Kanater drain after Mostorod drain discharge (sample No. B2). Also, TDS concentrations in drains water are higher than the permissible limits of law 48 (500 mg/L).

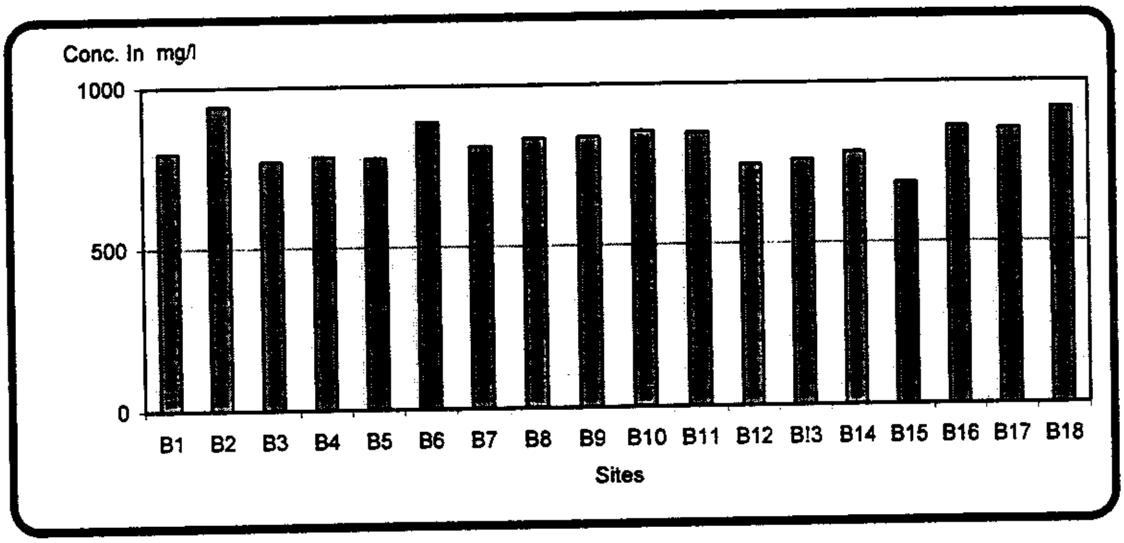


Fig. 4.4, Distribution of TDS in the drains water samples

Water quality for irrigation depending upon type and quantity of dissolved salts. These salts are carried with water to wherever it is used. In the case of irrigation, the salts are applied with the water and remain behind in the soil as water evaporates or is used by the crop (77).

According to the following classification of water by Rhoads et al. (78) Table 4.1, and the results of electrical conductivity and total dissolved solids shows that the River Nile water are non-saline water, wherever the drains water are slightly saline.

Table 4.1. Classification of water, **adapted from Rhoades et al. (1992)**

Water class	Electrical conductivity dS/m*	Dissolved solids mg/L	Type of water
Non-saline	< 0.7	< 500	Drinking and irrigation water
Slightly saline	0.7 - 2.0	500 -1500	Irrigation water
Moderately saline	2.0 - 10.0	1500 - 7000	Primary drainage water and groundwater
Highly saline	10.0 - 25.0	7000 - 15000	Secondary drainage water and groundwater
Very highly saline	25.0 - 45.0	15000 - 35000	Very saline groundwater
Brine	> 45.0	> 35000	Seawater

* dS/m = 1000 µS/m

There are many factors beside Total Dissolved Solids (TDS) and Electrical Conductivity (EC) that should be considered when evaluating the quality of irrigation water. To properly evaluate the quality of water, a complete chemical analysis is required. Such an analysis should include the determination of the following Cations (Ca^{++}, Mg^{++}, Na^{+} and K^{+}) and the following Anions (HCO_3^-, CO_3^{--}, SO_4^{--}, Cl^- and NO_3^-) (79).

4.1.4 Alkalinity

Alkalinity is a measure of the capacity of water to neutralize acids. Alkalinity of water originates due to the presence of carbonate, bicarbonate and hydroxide ions. Salts of weak acids, such as borate, silicates and phosphates, may contribute to the alkalinity in polluted or anaerobic water, but their contribution usually is negligible. Bicarbonate is the major form of alkalinity. Carbonates and hydroxide may be significant when algae activity is high. Alkalinity is significant in the treatment processes for potable water and wastewater. The alkalinity acts as pH buffer in coagulation and lime-soda softening of water.

According to the physicochemical analysis data in Appendix A, Table I, total alkalinity for the Nile River water ranging between 131 mg/L in Ismailia canal at El-Ameria water treatment plant output (sample No. A8) and 158 mg/L in Ismailia canal at El-Kahera for Oil Refining discharge (sample No. A11). The total alkalinity of the river Nile water samples is within the permissible limits of law 48 (not exceed 150 mg/L) except sample No. A11 and sample No. A12 are higher than the standard level of law 48.

For the drains water samples, total alkalinity, which are presented in Appendix A, Table II, range between 317 mg/L at El-Qalubia drain before mixing with Shebeen El-Kanater drain (sample No. B15) and 427 mg/L at El-Qalubia drain before mixing with Eskander drain (sample No. B12).

In large quantities, alkalinity imparts a bitter taste to water. The principle objection to alkaline water, however, is the reactions that can occur between alkalinity and certain cations in the water (80).

4.1.5 Hardness

Dissolved minerals, primarily divalent cations including calcium (Ca^{2+}), magnesium (Mg^{2+}), iron (Fe^{2+}), strontium (Sr^{2+}), zinc (Zn^{2+}), and manganese (Mn^{2+}) cause hardness in water. Calcium and magnesium ions usually are the only ions present in significant concentrations; therefore, hardness is generally considered to be a measure of the calcium and magnesium contents in water (81).

Waters commonly classified in terms of the degree of hardness as $CaCO_3$ mg/L table 4.2 as follows.

Table 4.2, Hardness classification according to Peavy et al(75) .

Hardness description	**Hardness as $CaCO_3$ mg/L**
Soft	< 50
Moderately hard	50 - 150
Hard	150 - 300
Very hard	> 300

The results of hardness in the Nile River water are presented in Appendix A, Table I, range between 115.45 mg/L as $CaCO_3$ at the front of Decorama company (sample No. A6) and 164.67 mg/L as $CaCO_3$ at El-Kahera for oil refining company (sample No. A11).

According to the above classification (Table 4.2), the Nile River water is moderately hard, except the sample No.A11, which has hard water (164.67 mg/L).

On the other hand, the results of hardness in the drains water, are presented in Appendix A, Table II, are considered to be hard water. The hardness as $CaCO_3$ ranges between 216.56 mg/L at Shebeen El-Kanater drain after El-Gafraa drain discharge (sample No. B4) and 300.05 mg/L at Shebeen El-Kanater drain after Mostorod drain discharge (sample No. B2).

4.2 Major Cations

4.2.1 Distribution of Sodium:

All natural waters contain some sodium because of its high solubility and it is one of the most abundant elements on the earth. It is found in the ionic form (Na^+) and in plant and animal matter, since it is an essential element for living organisms (8). The concentration of sodium in natural water is generally less than 200 mg/L, while it attains about 10,000 mg/L in seawater and about 25,000 mg/L in brines, (82).

In the Nile River water samples sodium concentrations, which are presented in Appendix A, Table I, and illustrated in Fig. 4.5 range between 17.82 mg/L at intake of El-Kahera for oil refining company (sample No. A10) and 23.50 mg/L at El-Kahera for oil refining company (sample No. A11).

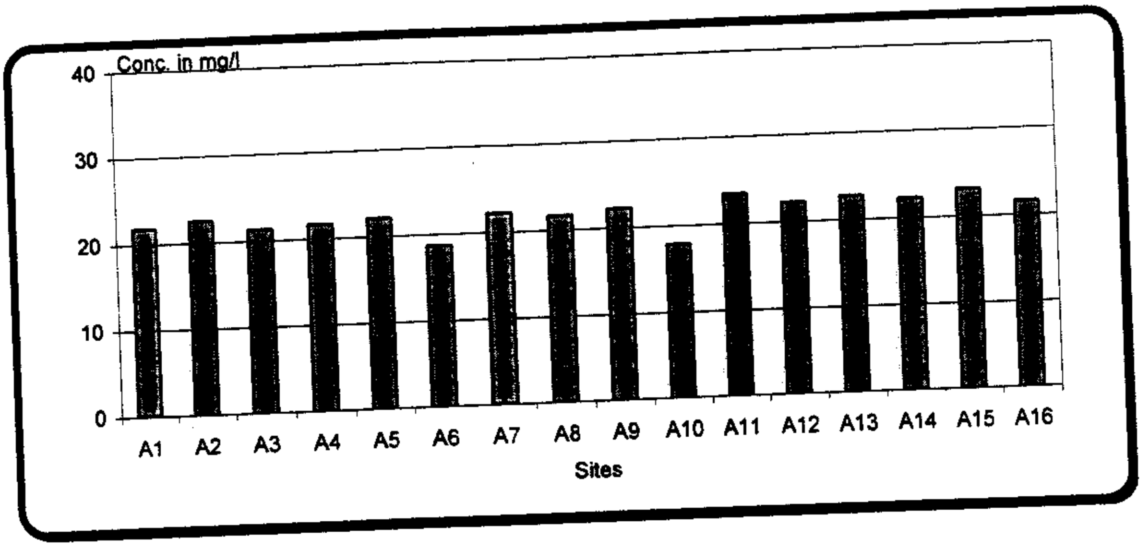


Fig. 4.5, Distribution of Na^+ in the Nile River water samples

In the drains water samples sodium concentrations are presented in Appendix A, Table II, and are illustrated in Fig. 4.6 range between 122 mg/L at El-Qalubia drain before mixing with Shebeen El-Kanater drain (sample No.B15) and 198 mg/L at Shebeen El-Kanater drain after Mostorod drain discharge (sample No. B2).

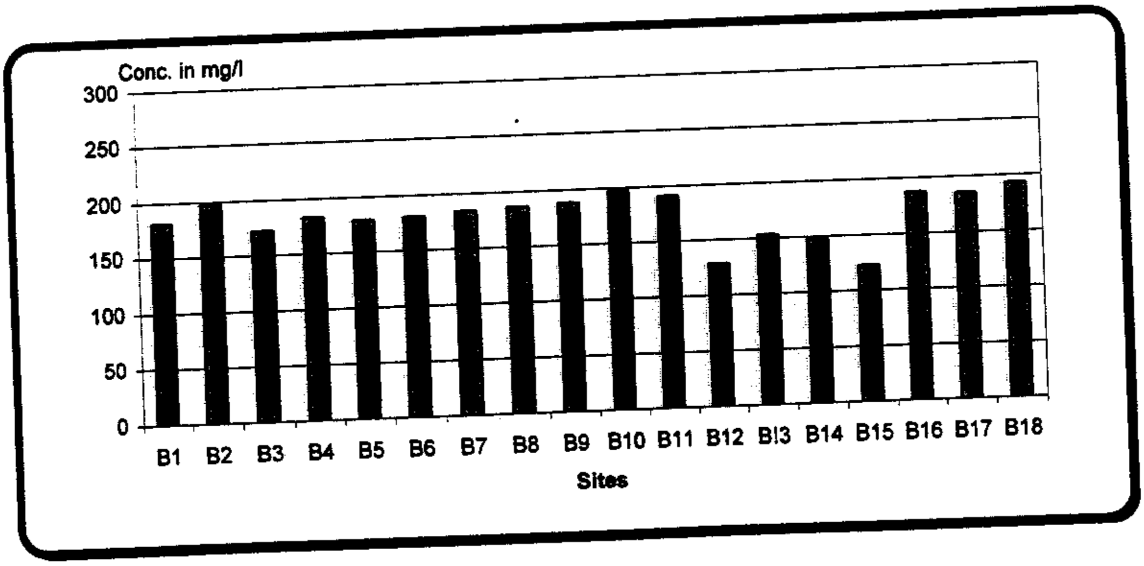


Fig. 4.6, Distribution of Na^+ in drains water samples

4.2.2 Distribution of Potassium:

Potassium (as K^+) is found in low concentrations in natural waters since rocks, which contain potassium, are relatively resistant to weathering. However, potassium salts are widely used in industry and fertilizers for agriculture and enter freshwaters with industrial discharges and run-off from agricultural land (7). The concentration of potassium in natural water is generally less than 10 mg/L, as much as 100 mg/L in hot springs, and about 25,000 mg/L in brines.

Potassium concentrations are presented in Appendix A, Table I, and are illustrated in Fig. 4.7 for the Nile River water samples range between 4.87 mg/L at intake of Ismailia canal (sample No. A5) and 6.09 mg/L at Abu-Zabaal fertilizer company discharge (sample No. A15).

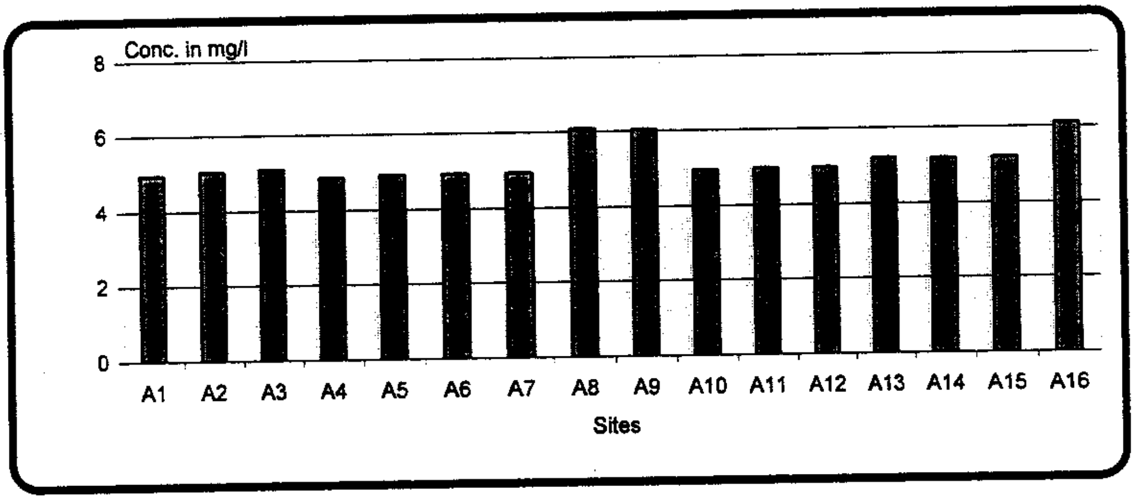


Fig. 4.7, Distribution of K^+ in the Nile River water samples

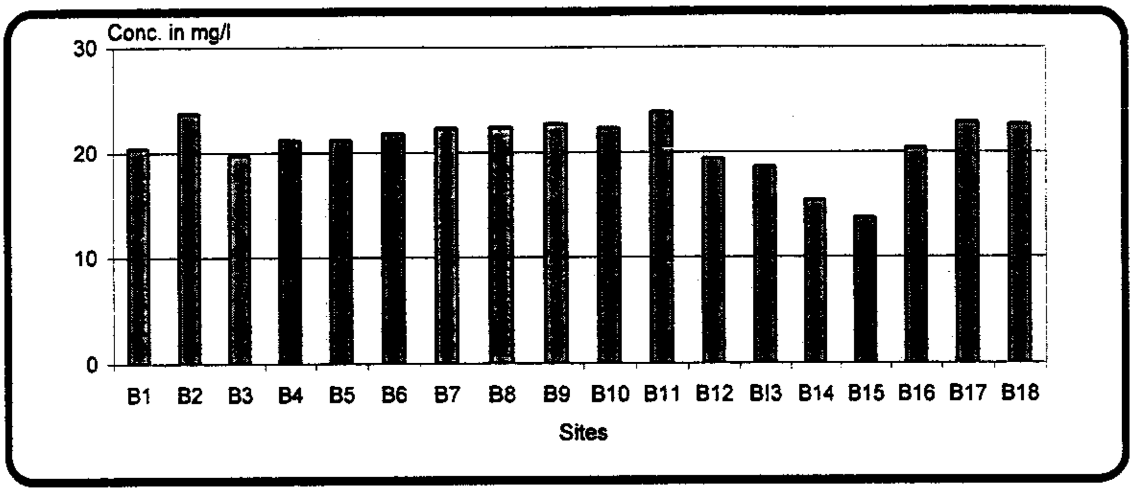


Fig. 4.8, Distribution of K^+ in the drains water samples

In drains water samples, potassium concentrations are presented in Appendix A, Table II, and are illustrated in Fig. 4.8 range between 13.70 mg/L at El-Qalubia drain before mixing with Shebeen El-Kanater drain (sample No.B15) and 23.8 mg/L at Shebeen El-Kanater drain before mixing with El-Qaluibia drain (sample No. B11).

4.2.3 Distribution of Calcium:

Calcium is present in all salts of water as Ca^{2+} and is readily dissolved from rocks rich in calcium minerals, particularly as carbonates and sulphates, especially limestone and gypsum. Industrial wastes and wastewater treatment, processes also contribute calcium to surface waters (9). The concentration of calcium in natural water is generally less than 100 mg/L, brines may contain as much as 75,000 mg/L (82).

Calcium concentrations are presented in Appendix A, Table I, and are illustrated in Fig. 4.9 for the Nile River water samples range between 33.37 mg/L in Ismailia canal at the front of Decorama company (sample

No. A6) and 53.10 mg/L at El-Kahera for oil refining company (sample No. A11).

In drains water samples, calcium concentrations, which are presented in Appendix A, Table II, and illustrated in Fig. 4.10 range between 48.76 mg/L at Shebeen El-Kanater drain before Sendowa drain and 71.35 mg/L at El-Qalubia drain before mixing with Eskander drain (sample No. B12).

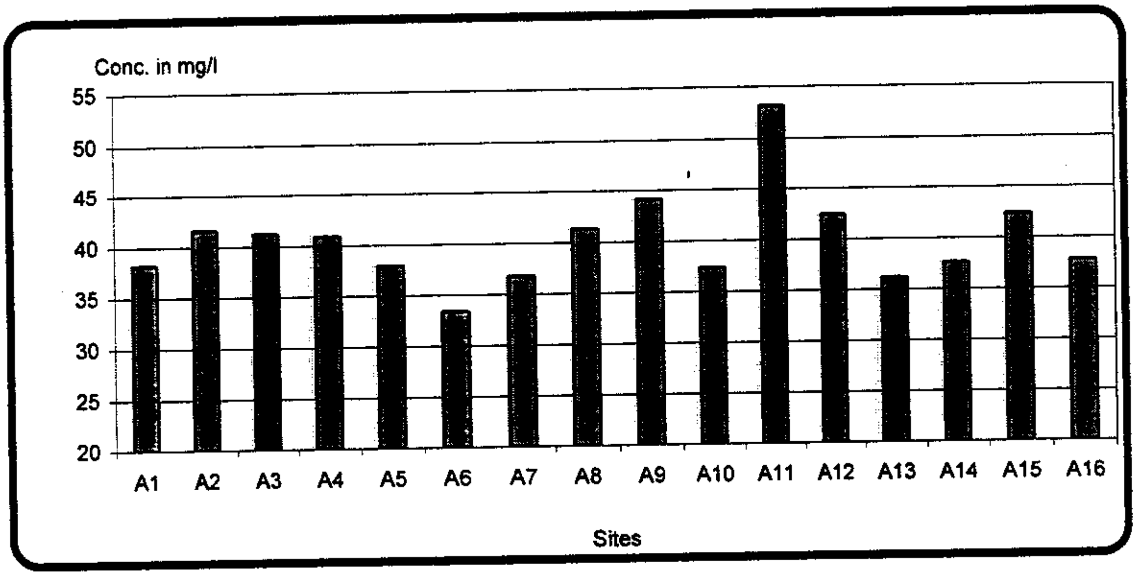


Fig. 4.9, Distribution of Ca^{2+} in the river Nile water samples

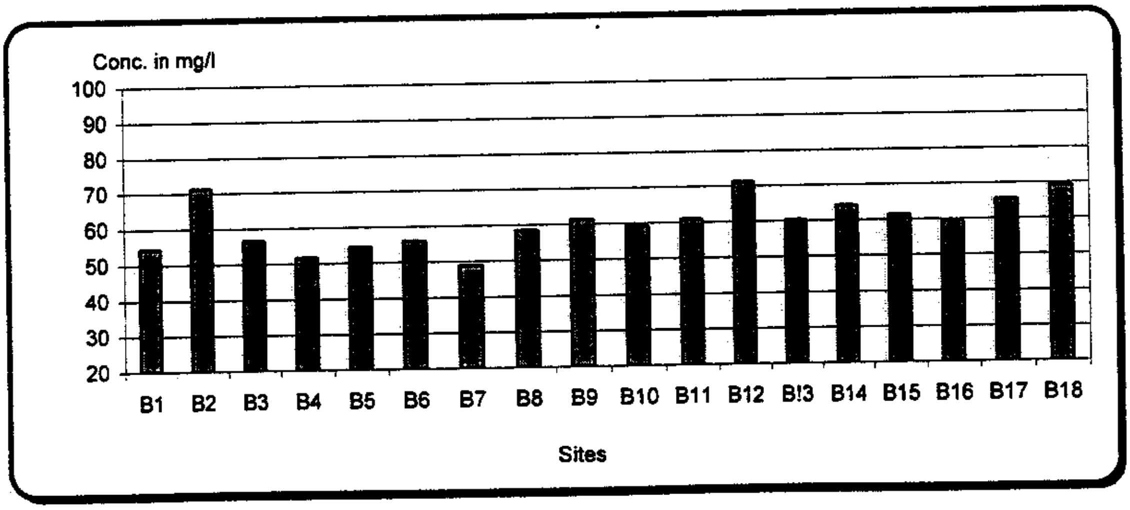


Fig. 4.10, Distribution of Ca^{2+} in the drains water samples

4.2.4 Distribution of Magnesium:

Magnesium is common in natural waters as Mg^{2-}, and along with calcium, is a main contributor to water hardness. Magnesium arises principally from the weathering of rocks containing Ferro magnesium minerals and from some carbonates rocks. Magnesium occurs in many organometallic compounds and in organic matter, since it is an essential element for living organisms. Natural levels of magnesium in freshwaters may be range from 1 to 100 mg/L, depending on the rock types within the catchments. The concentration of Mg^{2-} in natural water is generally less than 50 mg/L, ocean water contains more than 1000 mg/L and brines may contain as much as, 75000 mg/L magnesium, (76).

Magnesium concentrations are outlined in Appendix A, Table I, and are illustrated in Fig. 4.11 for the Nile River water samples range between 5.81 mg/L at intake of Ismailia canal (sample No. A5) and 7.80 mg/L in Ismailia canal at the front of Decorama company (sample No. A6).

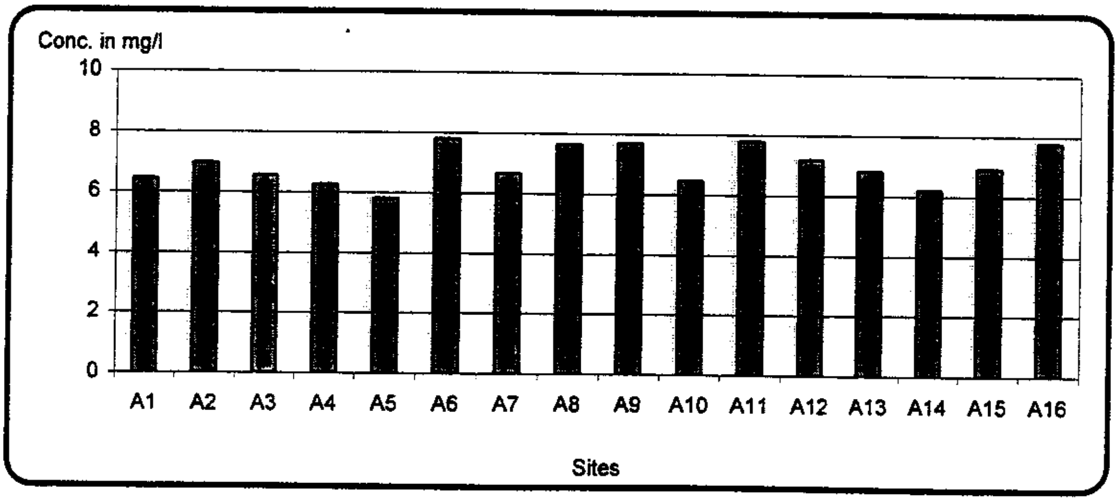


Fig. 4.11, Distribution of Mg^{2+} in the Nile River water samples

In drains water samples, magnesium concentrations are presented in Appendix A, Table II, and are illustrated in Fig. 4.12 range between 21.30 mg/L at Shebeen El-Kanater drain before Kafer Hamza drain (sample No. B5) and 31.80 mg/L at El-Qalubia drain before mixing with Shebeen El-Kanater drain (sample No.B15).

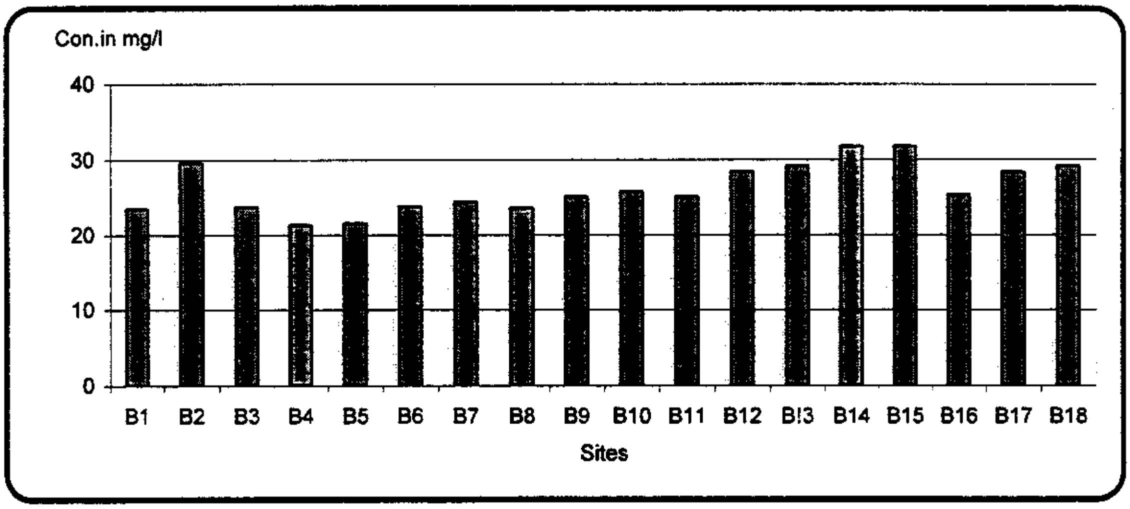


Fig. 4.12, Distribution of Mg^{2+} in the drains water samples

4.2.5 Distribution of Boron:

Boron is important in agriculture, small amounts are important to plant growth. Greater concentrations in soil and irrigation water are harmful for some plants such as lemon, or orange trees. The toxic concentration is as low as 1 mg/L. Boron concentrations, which are presented in Appendix A, Table 1,2, for the Nile River and drains water samples are less than 1.0 mg/L.

4.3 Major anions

4.3.1 Distribution of Fluoride

Fluoride occurs naturally in most soils and in many water supplies. For more than 30 years, fluoride has been added to supplies lacking sufficient natural quantities, for the purpose of reducing dental cavities. The analyst reports fluoride concentrations in terms of the free F^- ion. This form is probably predominant one in most water, but other varieties of dissolved fluorite are certainly possible. At low pH the form HF° occurred (76).

Fluoride concentrations are presented in Appendix A, Table I, and are illustrated in Fig. 4.13 for the Nile River water samples range between 0.26 mg/L at intake of El-Kahera for oil refining company (sample No. A10) and 0.41 mg/L in Ismailia canal after discharge of El-Kahera for oil refining (sample No. A12).

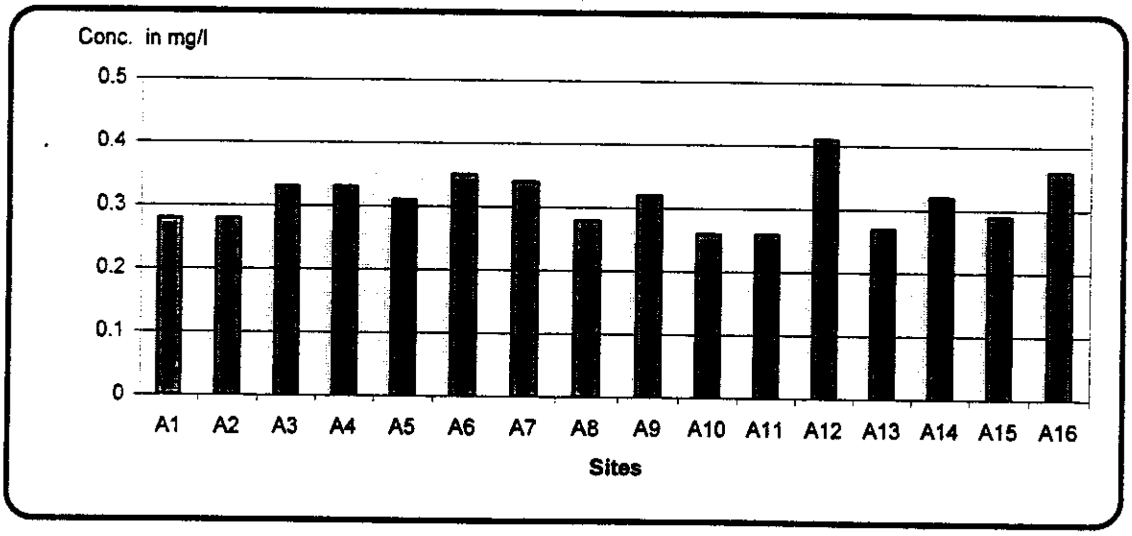


Fig. 3.13, Distribution of F^- in the Nile River water samples

In drains water samples, fluoride concentrations are presented in Appendix A, Table II, and are illustrated in Fig. 4.14 range between 0.26 mg/L in Shebeen El-Kanater drain before Tanan drain (sample No. B9) and 0.45 mg/L at El-Qalubia drain before mixing with Eskander drain (sample No. B12).

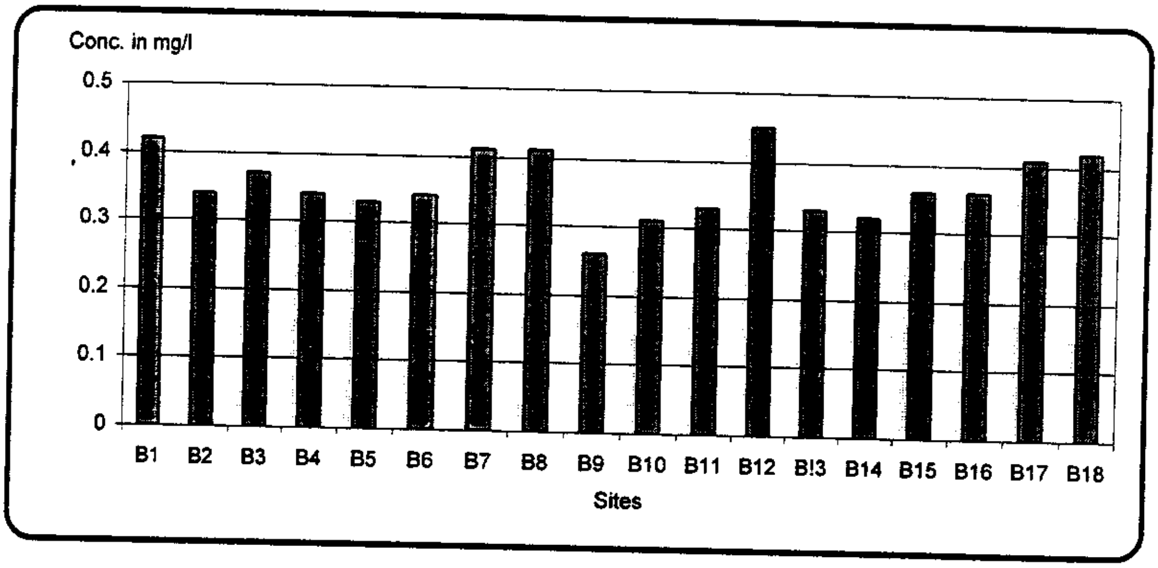


Fig. 4.14, Distribution of F^- in the drains water samples

The fluoride concentrations of the River Nile and drains water samples are within the permissible limits of law 48 (not exceed 0.5 mg/L).

4.3.2 Distribution of Chloride:

Most chlorine occurs as chloride (Cl^-) in solution. It enters surface waters with the atmospheric deposition of oceanic aerosols, with the weathering of some sediment rocks, mostly rock salt deposits, and from industrial and sewage effluents, and agricultural and road run-off (9).

Chloride ion is present in all natural waters with an average concentration of 3 mg/L in rainwater and 19000 mg/l in seawater (76). Commonly the concentration of chloride in natural water is less than 10 mg/L in humid regions, but up to 1000 mg/L in more arid regions. About 200,000 mg/L is found in brines.

Chloride ion concentrations are presented in Appendix A, Table I, and are illustrated in Fig. 4.15 for the Nile River water samples range between 12.21 mg/L in Ismailia canal at the front of Decorama company (sample No. A6) and 29.21 mg/L in Ismailia canal at El-Ameria water treatment plant output (sample No. A8).

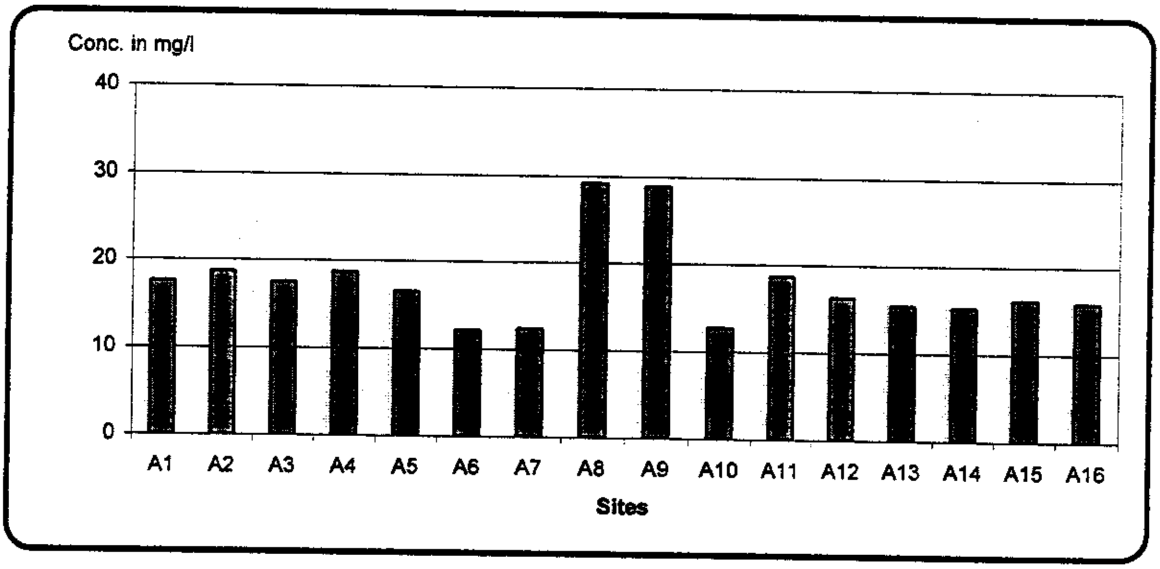


Fig. 4.15, Distribution of Cl^- in the Nile River water samples

In drains water samples, chloride concentrations are presented in Appendix A, Table II, and are illustrated in Fig. 4.16 range between 117.00 mg/L at El-Qalubia drain before mixing with Shebeen El-Kanater drain (sample No.B15) and 221.00 mg/L at Shebeen El-Kanater drain after Mostorod drain discharge (sample No. B2).

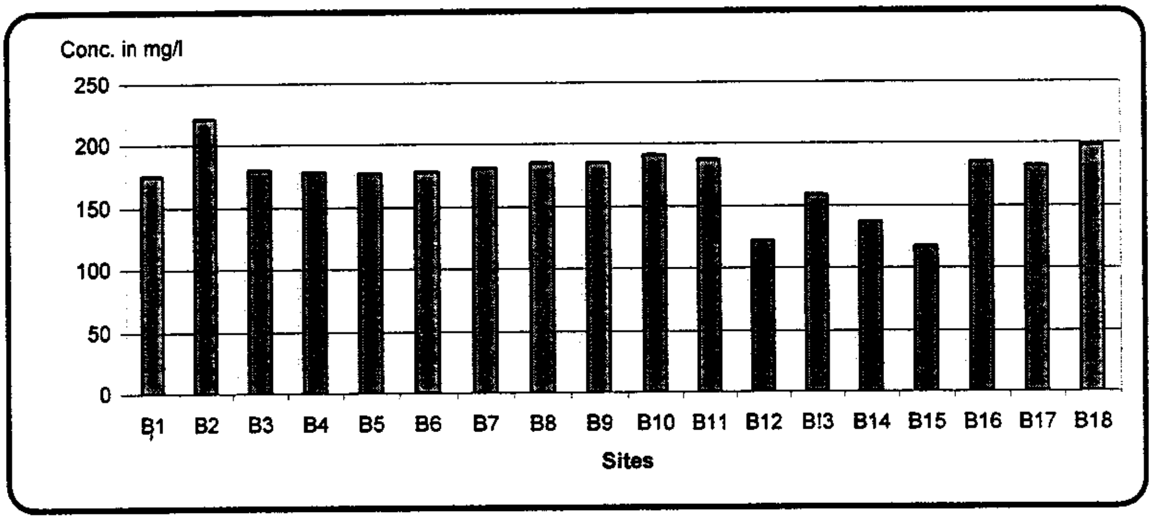


Fig. 4.16, Distribution of Cl^- in the drain water samples

4.3.3 Distribution of Nitrate:

In water, the most common identified contaminant is dissolved nitrogen in the form of nitrate (NO_3^-). This contaminant is more widespread due to agricultural activities and disposal of sewage on or beneath the land surface (10,82). The natural sources of nitrate in water are nitrogen fertilizers as ammonium sulfate $(NH_4)_2SO_4$, ammonium nitrate NH_4NO_3 and urea $CO(NH_2)_2$.

Nitrate concentrations are presented in Appendix A, Table I, and are illustrated in Fig. 4.17 for the Nile River water samples range between 1.8 mg/L in Nile River before Shoubra power station (sample No. A1) and 14.80 mg/L in Ismailia canal after Abu-Zabaal fertilizer company discharge (sample No. A16).

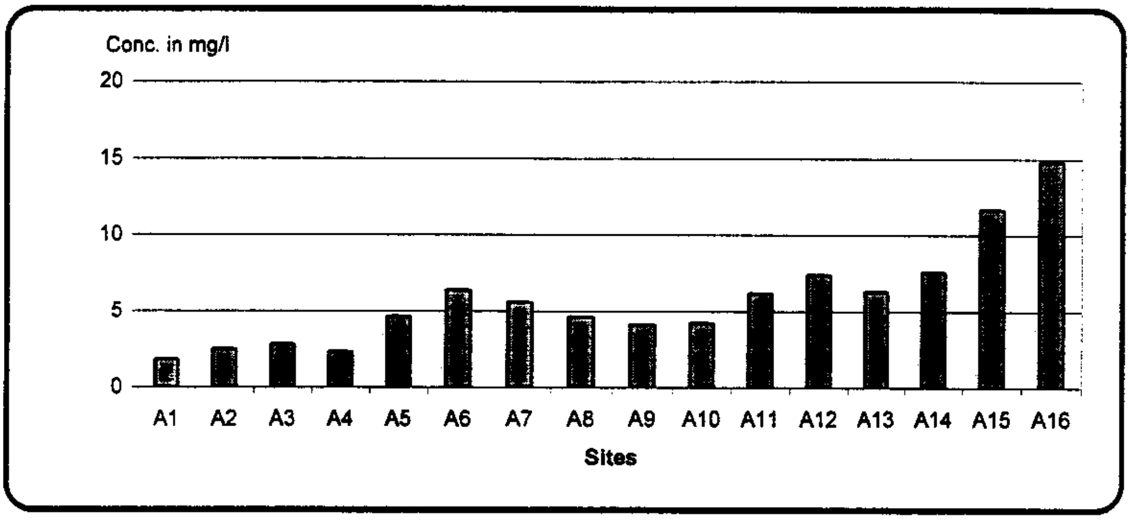


Fig. 4.17, Distribution of NO_3^- in the Nile River water samples

In drains water samples, nitrate concentrations are presented in Appendix A, Table II, and are illustrated in Fig. 4.18 range between 6.40 mg/L at Shebeen El-Kanater drain after Mostorod drain discharge (sample No. B2) and 19.30 mg/L at El-Qalubia drain after Talha drain (sample B18).

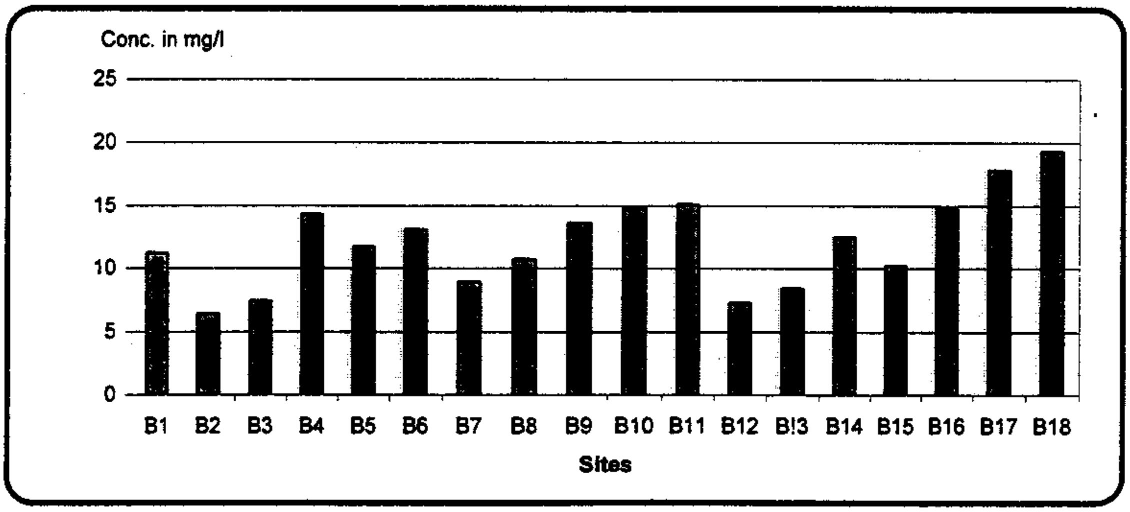


Fig. 4.18, Distribution of NO_3^- in the drains water samples

The nitrate concentrations of the river Nile and drains water samples are within the permissible limits of law 48 (not exceed 45 mg/L).

The relatively high concentration of nitrate in drains water might be due to drainage of irrigation water, which is rich in nitrate fertilizers as well as, animal enrichment contamination.

4.3.4 Distribution of Sulfate:

Sulfate arises from the atmospheric deposition of oceanic aerosols and leaching of sulfur compounds, either as sulfate minerals such as gypsum or as sulfide minerals such as pyrite. It is the stable, oxidized form of sulfur and readily soluble in water (with exception of lead, barium, and strontium sulfates which precipitate). Industrial discharges and atmospheric precipitation can also add significant amounts of sulfate to surface water.

Sulfate concentrations are presented in Appendix A, Table I, and are illustrated in Fig. 4.19 for the Nile River water samples range between 18.40 mg/L in Ismailia canal at the front of Decorama company (sample No. A6) and 47.40 mg/L at Abu-Zabaal fertilizer company discharge (sample No. A15).

In drains water samples, sulfate concentrations are presented in Appendix A, Table II, and are illustrated in Fig. 4.20 range between 66.20 mg/L at El-Qalubia drain before mixing with Eskander drain (sample No. B12), and 121.2 mg/L at El-Qalubia drain before Talha drain (sample No.B17).

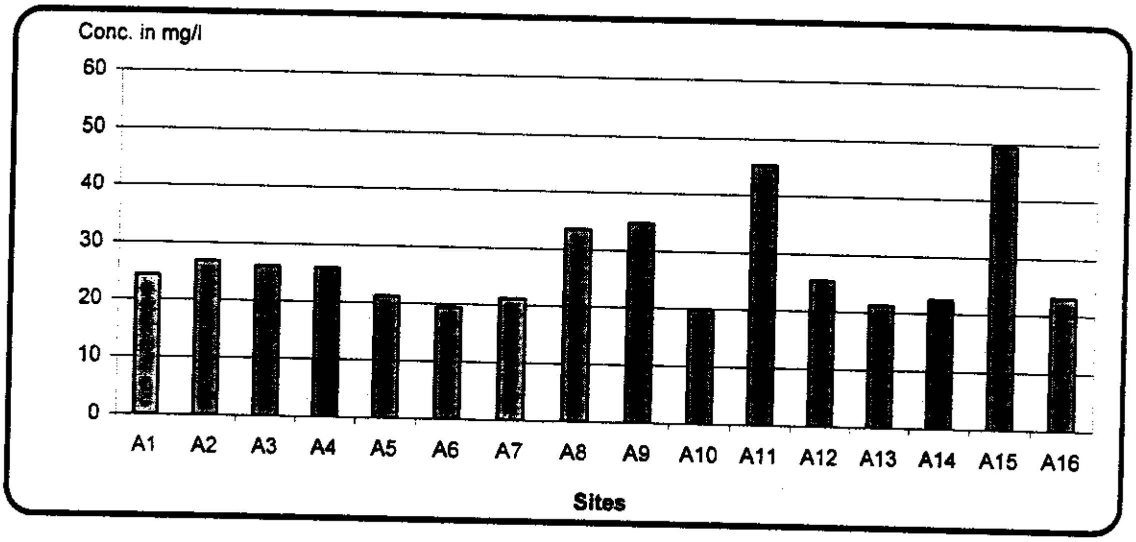


Fig. 4.19, Distribution of SO_4^{-2} in the Nile River water samples

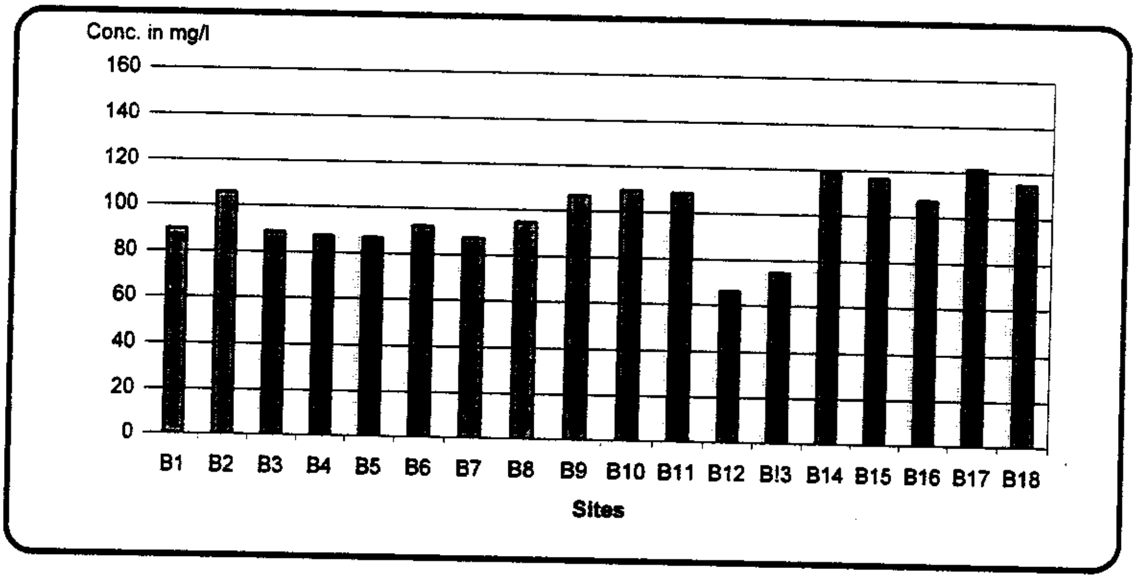


Fig. 4.20, Distribution of SO_4^{-2} in the drains water samples

Sulfate concentrations in the Nile River and drains water samples are within the permissible limits of law 48 (not exceed 200 mg/L).

4.3.5 Distribution of Phosphate:

Phosphorus, like nitrogen, has a great importance in water supply system and in aquatic environment. The use of phosphorus fertilizers has a potential for increasing the phosphorus content in water. Phosphates play an important role in plant and animal metabolism and thus occur in their waste products. Domestic detergent and industrial sewage effluents represent important sources of phosphorus in natural water (83).

Phosphate concentrations, which are presented in Appendix A, Table I, for the Nile River water samples are less than 1.0 mg/L (the permissible limits of law 48).

In drains water samples, phosphate concentrations are presented in Appendix A, Table II, and are illustrated in Fig. 4.21 range between 0.92 mg/L at El-Qalubia drain before mixing with Eskander drain (sample No.B12) and 11.87 mg/L at El-Qalubia drain after Talha drain (sample B18). All drains water samples are higher than the permissible limits of law 48 (not exceed 1.0 mg/L) except sample No. B12.

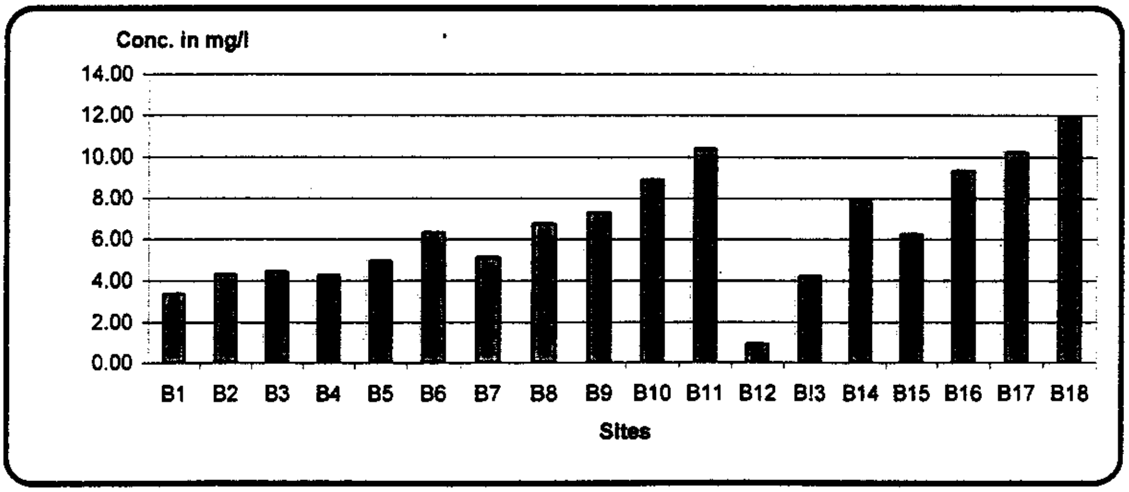


Fig. 4.21, Distribution of PO_4^{3-} in the drains water samples

Presence of phosphorus in water is mainly attributed to the effect of organic wastes and irrigation water rich in phosphates. Chhatwal (84) found that more than 80 % of the nitrogen and 75 % of the phosphorus added to surface water originate from man-made sources.

FAO guidelines, in Table 4.3, are used to evaluate the water quality for irrigation using the problem approach (77).

Table 4.3, Laboratory parameters needed to Evaluate irrigation water quality.

Parameters	**Restriction on water use**		
	None	**Slight to Moderate**	**Severe**
Salinity			
EC (dS/m)	<0.7	0.7 - 3.0	>3.0
TDS (mg/L)	<450	450 – 2000	>2000
Ion Toxicity			
Sodium (Na^+) in meq/L	<3	3 – 9	>9
Chloride (Cl^-) in meq/L	<4	4 -10	>10
Boron (B^-) in meq/L	<0.7	0.7 – 3.0	>3
Nitrate (NO^-_3) in mg/L	<5	5 – 30	>30
Miscellaneous Effects			
Sodium adsorption Ratio SAR	0-3	3-6	>6

- Adapted from **Ayers and Westcott 1985.**

Elevated sodium can degrade soil structure thereby restricting water movement and affecting plant growth. The sodium adsorption ratio (SAR) estimate the degree to which, sodium will be adsorbed and replace the calcium and magnesium ions in soil.

$$\mathbf{SAR} = \frac{Na^{+}}{\sqrt{\frac{(Ca+Mg)}{2}}}$$

Where:

Na, Ca, and Mg are expressed in meq/L

According to the above evaluation, SAR values for the River Nile that are presented in Appendix A, Table I, range from 0.71 to 0.91, and has no restriction. The SAR values for the drains are presented in Appendix A, Table II, ranging from 3.15 to 5.41, give a slight degree of restriction on the use of these water for irrigation.

Toxicity normally results when certain ions are taken up with soil water and accumulate in the leaves during water transpiration to such an extent that the plant is damaged. The degree of damage depends upon time, concentration, crop sensitivity and crop water use. The usual toxic ions in irrigation water are chloride, sodium and boron. Each can cause damage, individually or in combination.

For the River Nile Na, Cl and B values (in meq/L), which are presented in Appendix (B) do not cause toxicity problem but for the drains may cause moderate problem.

4.4 Trace Metals

4.4.1 Distribution of Aluminum

The major source of aluminum in freshwater is discharge of alum sludge from municipal treatment plants. Alum sludge are produced when alum or aluminum sulfate ($Al_2(SO_4)_3.4H2O$) is used for coagulation and flocculation of raw water supplies to remove turbidity and/or color. The discharge of sludge increases aluminum residues in water (85).

Aluminum concentrations are presented in Appendix A, Table I and are illustrated in Fig. 4.22 for the Nile River water samples range between 0.06 mg/L in Ismailia canal at Abu-Zabaal bridge (sample No. A13) and 6.41 mg/L at El-Kahera for oil refining company (sample No. A11).

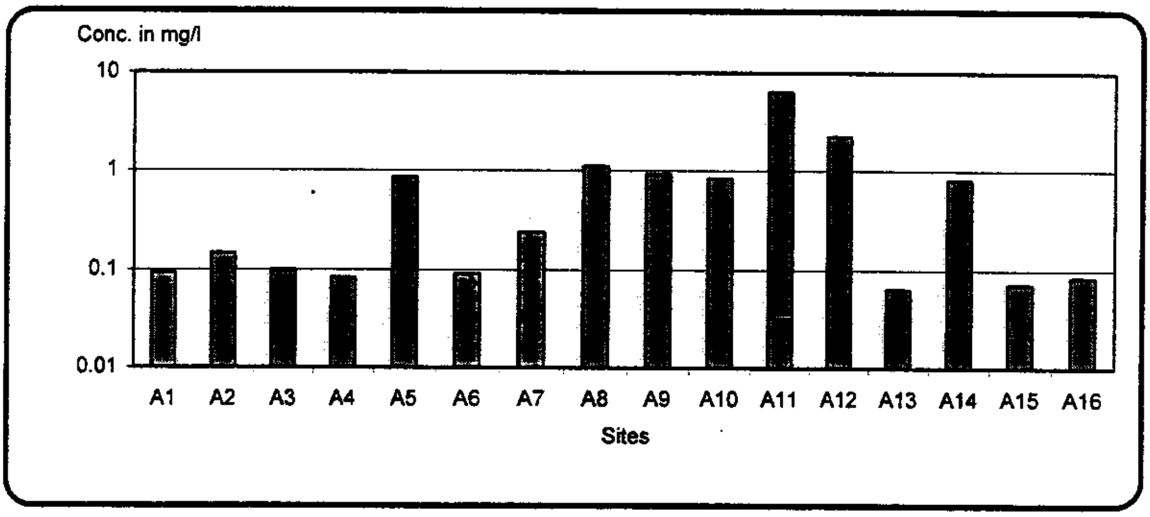


Fig. 4.22, Distribution of Al in the Nile River water samples

In drains water samples, aluminum concentrations, which are presented in Appendix A, Table II, and illustrated in Fig. 4.23 range between 0.09 mg/L at El-Qalubia drain before mixing with Eskander drain (sample No. B12) and 0.63 mg/L at Shebeen El-Kanater drain after Mostared drain discharge (sample No. B2).

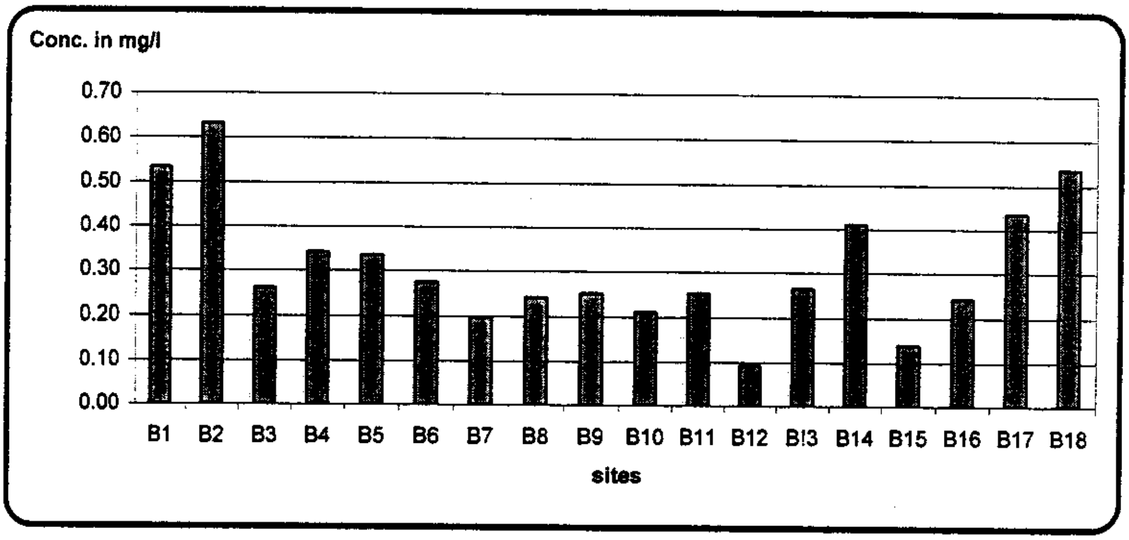


Fig. 4.23, Distribution of Al in the drains water samples

4.4.2 Distribution of Barium

Most episodes of barium contamination of water come from natural geological deposits and from spills of drilling fluids, rather than from industrial and municipal discharges (85).

Barium concentrations are presented in Appendix A, Table I, for the Nile River water samples range between 0.02 mg/L in Nile River after Shoubra power station (sample No. A4) and 0.06 mg/L in Ismailia canal at El-Ameria water treatment plant output (sample No. A9).

In drains water samples, barium concentrations are presented in Appendix A, Table II, and are illustrated in Fig. 4.24, range between 0.05 mg/L at Shebeen El-Kanater drain (sample No. B5, B6, B7, and B8) and 0.12 mg/L, at El-Qalubia drain before Talha drain (sample No.B17).

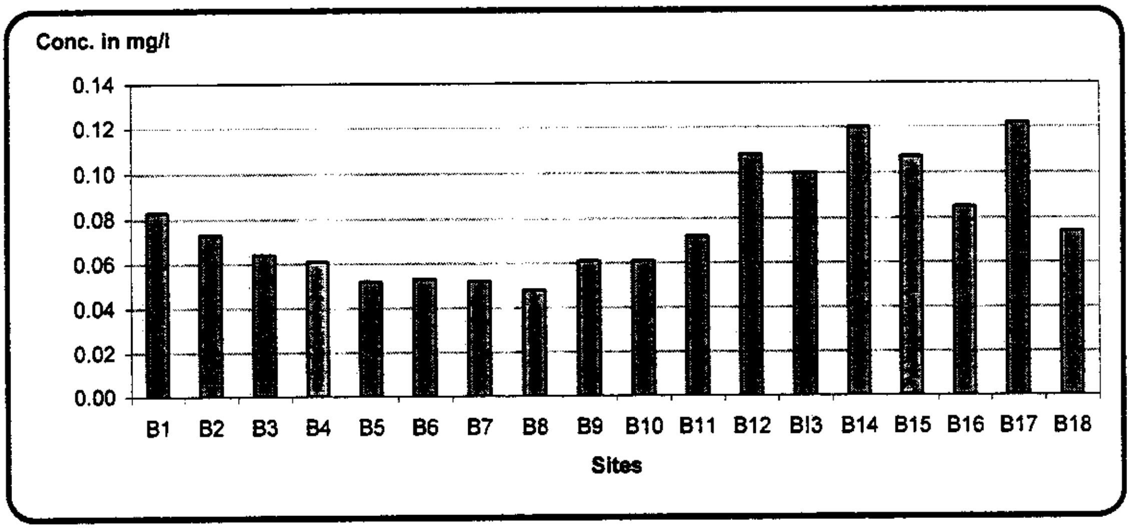


Fig. 4.24, Distribution of Ba in the drains water samples

4.4.3 Distribution of Cadmium:

Cadmium does not exist in nature as native metal but principally as sulfide ore namely greenokite (CdS), which is strongly associated with the zinc sulfide as sphalerite. In industry, cadmium is used mainly for electroplating on other metal to prevent corrosion, for paint, printing ink, plastics, electrical batteries and fluorescent. Many of these uses will tend to make the element available to water that comes in contact with buried wastes. Another factor of importance is the tendency for cadmium to enter the atmosphere through vaporization at high temperature. Therefore, cadmium may be liberated to the environment in metallurgical processes and in the combustion of fossil fuel (76).

Cadmium concentrations are presented in Appendix A, Table I, for the Nile River water samples are less than 0.01 mg/L (the permissible limits of law 48), except sample No. A11 (0.012 mg/L) and sample No. A15 (0.013 mg/L) in Ismailia canal.

In drains water samples, cadmium concentrations are presented in Appendix A, Table II, and are illustrated in Fig. (4.25), range between 0.01 mg/L at El-Qalubia drain before mixing with Eskander drain (sample No. B12) and 0.43 mg/L in El-Qalubia drain (sample No. B14). All drains water samples exceed the permissible limits of law 48 (not exceed 0.01 mg/L) except samples B1 and B12.

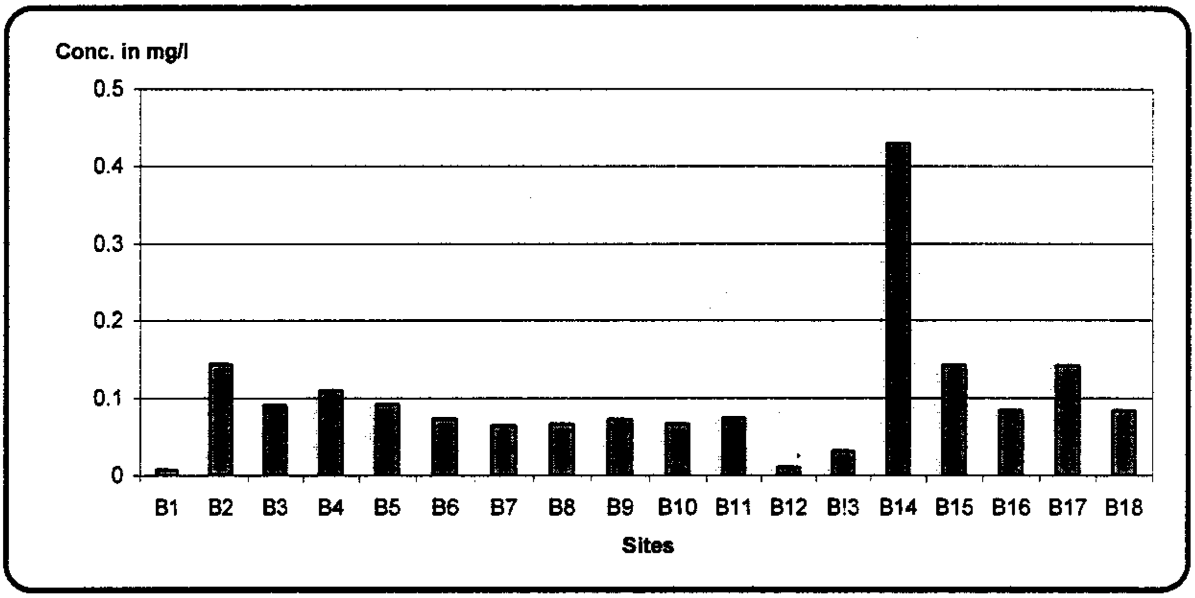


Fig. 4.25, Distribution of Cd in the drains water samples

The presence of cadmium in water samples is mainly due to industrial discharge wastes in the area under study.

4.4.4 Distribution of Chromium

The primary sources include domestic wastewater from both central and no central sources, manufacturing processes involving metals, and dumping sewage sludge (85). Chromium has several possible oxidation states. Thermodynamic data given by Latimer (86) shows that Cr^{+3} and Cr^{+6} species are stable in water and solubility of chromium is less than 0.5 µg/L between pH 8.0 and 9.5.

Chromium concentrations are presented in Appendix A, Table I, for the Nile River water samples are less than 0.05 mg/L (the permissible limits of law 48).

In drains water samples, chromium concentrations are presented in Appendix A, Table II, and illustrated in Fig. 4.26, are more than 0.01 mg/L (the permissible limits of law 48) except samples B12 and B13.

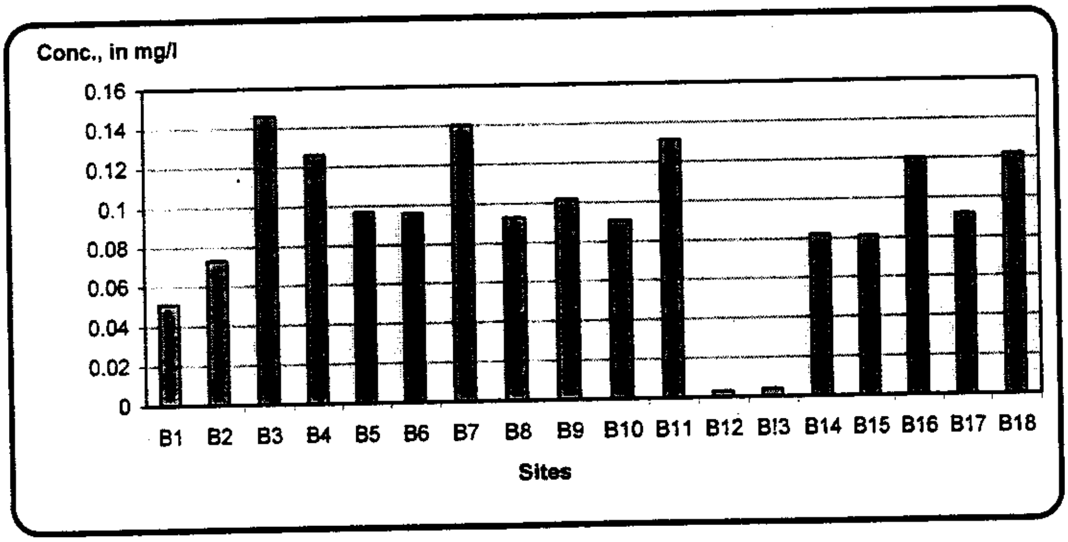


Fig.4.26, Distribution of Cr in drains water samples

4.4.5 Distribution of Copper

Most copper minerals are relatively insoluble and hence little copper is found in natural water. However, Cu^{+2} may be present in water from disintegration and weathering of rocks containing the element. Also, copper is available to surface water and ground water, due to the extensive use of agricultural pesticides sprays containing copper compounds. It is an essential element in human metabolism, but can cause anemia, disorder of bone and connective tissue, and liver damage at excessive levels.

The toxicity of Cu^{+2} depend upon the hardness and the pH of the water, therefore, it is more toxic in soft water and in water with alkalinity (9).

Copper concentrations are presented in Appendix A, Table I, II for the Nile River and drains water samples are less than 1.0 mg/L (the permissible limits of law 48).

4.4.6 Distribution of Iron:

Iron is the most abundant metallic element in the earth's outer crust. Concentrations present in water are generally small. Iron residues in surface water are extremely variable, reflecting differences in underlying bedrock, erosion, and to a lesser degree, industrial and municipal discharges. The primary oxidation states of iron in water are Fe^{+2} (ferrous) and Fe^{+3} (ferric). In most surface water, Fe^{+3} (ferric) predominates and, when combined with its salts, is practically insoluble at least in aerobic water; While Fe^{+2} (ferrous) is soluble and dominates under aerobic condition (85).

Iron concentrations are presented in Appendix A, Table I, for the Nile River water samples are less than 1.0 mg/L (the permissible limits of law 48).

In drains water samples, iron concentrations are presented in Appendix A, Table II, and are illustrated in Fig. 4.27, range between 0.37 mg/L at El-Qalubia drain before mixing with Eskander drain (sample No. B12) and 2.01 mg/L at Shebeen El-Kanater drain after Mostorod drain discharge (sample No. B2). Most samples are higher than the permissible limits of law 48 (not exceed 1.0 mg/L).

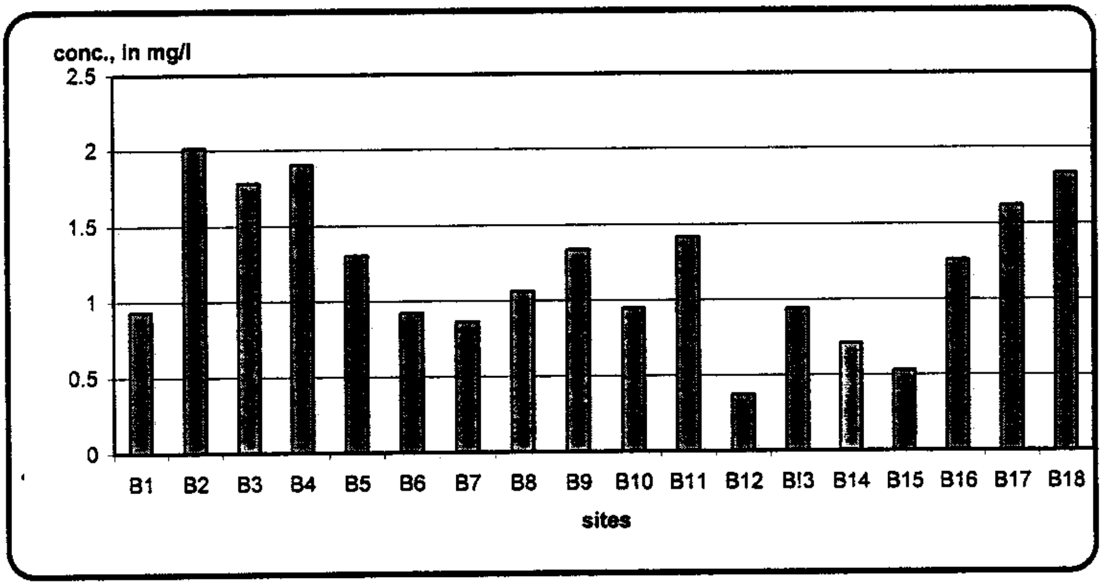


Fig., 4.27, Distribution of Fe in drains water samples

4.4.7 Distribution of Manganese:

Manganese does not occur naturally as a metal but is found in various salts and minerals, frequently in association with iron compounds. The principal manganese-containing substances are manganese dioxide, pyrolusite, manganese carbonate, and manganese silicate (rhodonitem). Manganese is present in ground water primarily as the divalent ion (Mn^{2+}) due to the lack of subsurface oxygen. Surface water may contain combination of manganese in various oxidation states as soluble complexes or as suspended particles. Manganese is an essential element in plant metabolism, and it is to be expected that organic circulation of manganese can influence its occurrence in the natural water system. The manganese compounds are generally soluble in water, but the concentration in surface water is limited by the formation of $MnCO_3$, which has a limited solubility.

Manganese concentrations, are presented in Appendix A, Table I, for the Nile River water samples are less than 0.5 mg/L (the permissible limits of law 48), except sample No. A11 (0.97 mg/L), in Ismailia canal.

In drains water samples, manganese concentrations are presented in Appendix A, Table II, and illustrated in Fig. 4.28, are higher than 0.5 mg/L (the permissible limits of law 48).

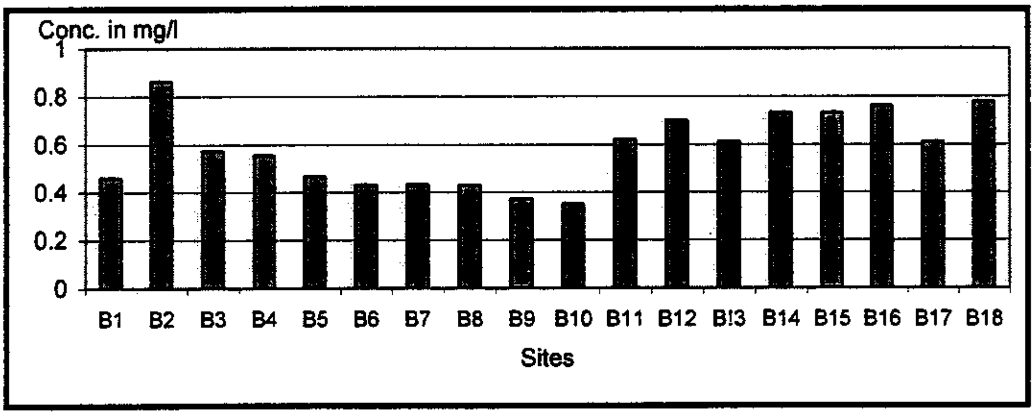


Fig., 4.28, Distribution of Mn in drains water samples

The presence of manganese in the drains water is mainly due to excess irrigation water.

4.4.8 Distribution of Nickel

Nickel is an important industrial metal. It is used extensively in stainless steel and other corrosion-resistant alloys and to a lesser extent for other purposes. The major source of discharge is municipal wastewater followed by smelting and refining of nonferrous metals (69). Because of its extensive cultural use, nickel can be contributed to the environment in significant amounts by waste disposal.

Nickel concentrations are presented in Appendix A, Table I, II, for the Nile River and drains water samples are less than 0.1 mg/L (the permissible limits of law 48) except samples B1, B2, and B4 in Shebeen El-Kanater drain.

4.4.9 Distribution of Lead:

Lead is rarely found as free metal in nature, but it is present in several minerals, principally in galena (PbS), anglesite ($PbSO_4$) and cerrusite ($PbSO_3$). The presence of lead in water usually indicates contamination from metallurgical wastes or from lead-containing industries. Lead enters the aquatic environment through precipitation of lead dust fallout, erosion and leaching of soil, municipal and industrial waste discharges and runoff of fallout deposits from streets and other surfaces (83). Also, large amounts are released in the smelting of ores, burning of coal and combustion of gasoline. The adsorption of lead on organic and inorganic sediment surfaces and the co-precipitation of lead with manganese oxide also led to maintain low concentration levels in surface and groundwater. Water having lower pH and alkalinity can retain larger concentrations. The concentrations of lead in rainwater and snow attain 0.0001 mg/L or more in areas subjected to substantial air pollution (76).

Lead concentrations, which are presented in Appendix A, Table I, and are illustrated in Fig. 4.29 for the Nile River water samples range between 0.01 mg/L in the Nile River before Shobra power station (sample No. A10) and 0.11 mg/L in Ismailia canal at the front of Decorama company (sample No. A6). Lead concentrations in most of the samples are higher than the permissible limits of law 48 (not to exceed 0.05 mg/L).

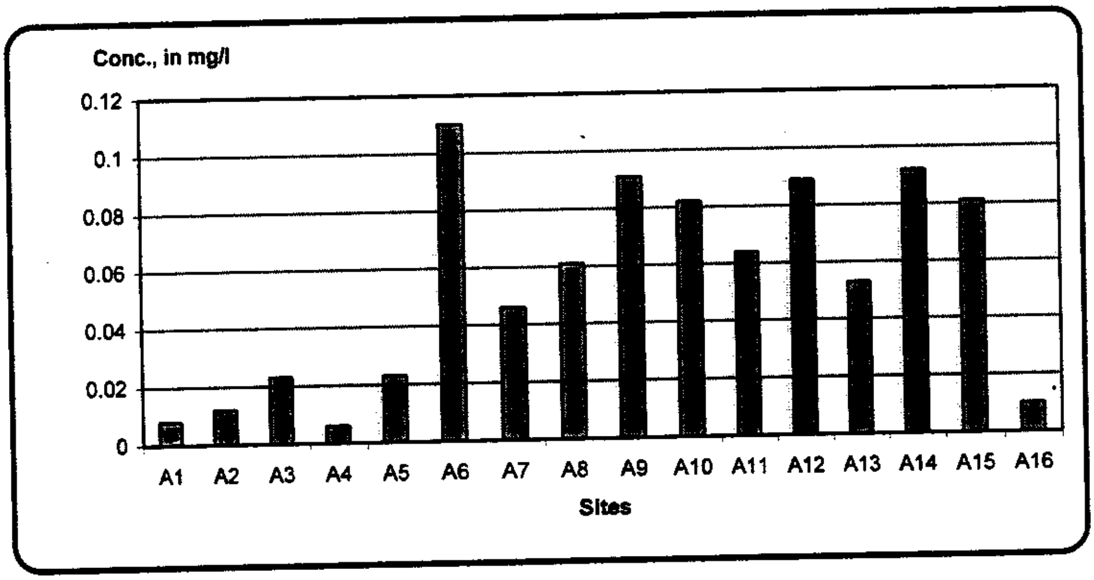


Fig., 4.29, Distribution of Pb in the Nile River water samples

In drains water samples, lead concentrations are presented in Appendix A, Table II, and are illustrated in Fig. 4.30, range between 0.06 mg/L at El-Qalubia drain before mixing with Eskander drain (sample No. B12) and 0.77 mg/L at Shebeen El-Kanater drain after

Mostorod drain discharge (sample No. B2). All sample concentrations are less the permissible limits of law 48 (not to exceed 0.5 mg/L) except sample B2 (.077 mg/L), B6 (0.65 mg/L), and B7 (0.66 mg/L).

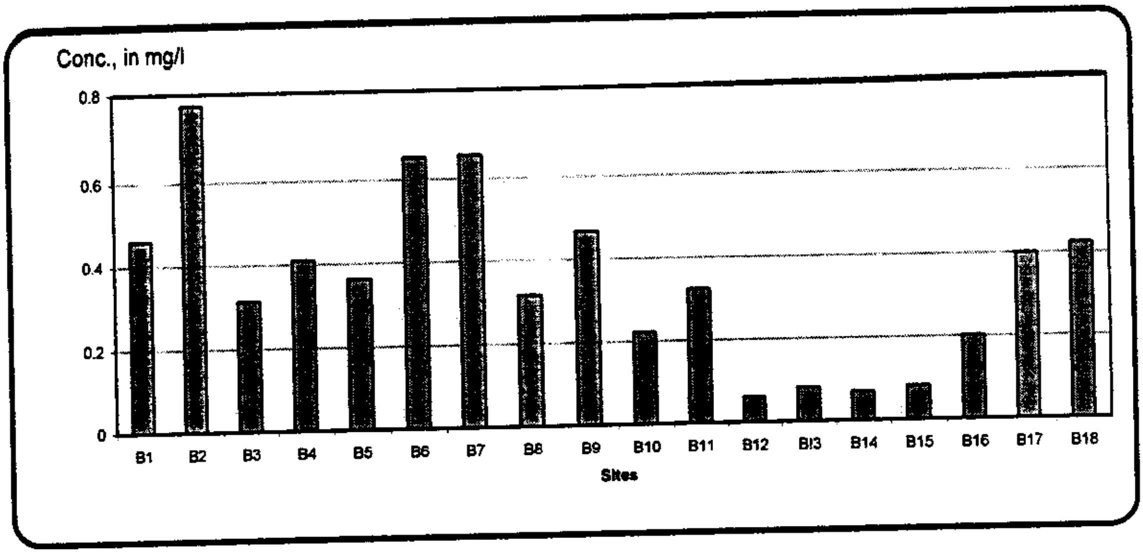


Fig., 4.30, Distribution of Pb in drains water samples

Presence of lead in the River Nile water in the area under study is mainly related to precipitation of lead dust fallout as a result of heavy traffic and condensed human population.

4.4.10 Distribution of Zinc

Zinc has about the same abundance in crusted rocks as copper or nickel. However, zinc has only one oxidation state, Zn^{2+} and tends to be substantially more soluble in most types of natural water than the other two metals. Zinc is essential in the metabolism in plants and animals.

Zinc concentrations are presented in Appendix A, Table I, II, for the Nile River and drains water samples are less than 1.0 mg/L (the permissible limits of law 48).

4.5 Organic Matter

Most freshwaters contain organic matter, which can be measured as total organic carbon (TOC). For comparative purposes, an indication of the amount of organic matter present can be obtained by measuring related properties, principally the biochemical oxygen demand (BOD) or the chemical oxygen demand (COD). The COD usually includes all, or most organic matter in the samples, COD > BOD > TOC.

4.5.1 Total Organic Carbon

Organic carbon in freshwaters arises from living material and also as a constituent of many waste materials and effluents. Consequently, the total organic matter in water can be useful indication of the degree of pollution, particularly when concentrations can be compared upstream and downstream of potential sources of pollution, such as sewage or industrial discharges or urban areas. In surface waters, total organic carbon concentrations are generally less than 10 mg/L, unless the water receives municipal or industrial wastes. In such situations, TOC concentrations may exceed 100 mg/L (TOC concentrations in municipal wastewater range from 10 to < 100 mg/L, depending on the level of wastewater treatment) (9).

TOC concentrations are presented in Appendix A, Table I, and are illustrated in Fig. 4.31 for the Nile River water samples range between 2.73 mg/L in the Nile River before shoubra power station (sample No. A1) and 8.75 mg/L in Ismailia canal at discharge of El-kahera for oil refining (sample A11).

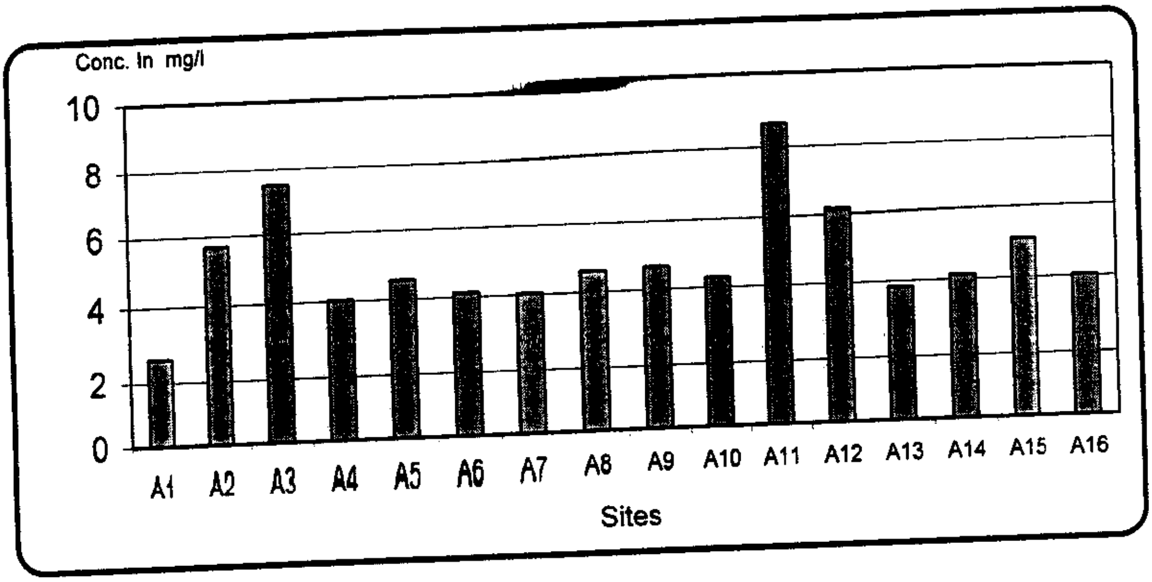


Fig. 4.31, Distribution of TOC in the Nile River water samples

In drains water samples, TOC concentrations are presented in Appendix A, Table II, and are illustrated in Fig. 4.32, range between 16.84 mg/L in Qaliuobia drain before mixing with Shebeen El- Kanater drain (sample B15) and 62.47 mg/L in Shebeen El-Kanater drain before mostorod drain discharge (sample No. B1).

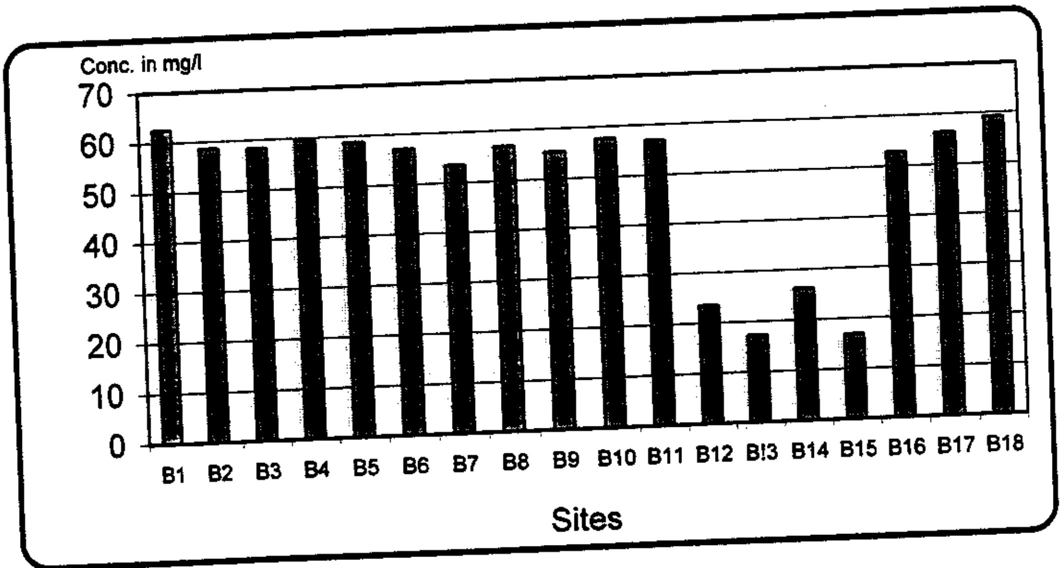


Fig.4.32, Distribution of TOC in drains water samples

4.5.2 Chemical Oxygen Demand

The chemical oxygen demand (COD) is a measure of the oxygen equivalent of organic matter in a water sample that is susceptible to oxidation by strong chemical oxidant, such as dichromate. The concentration of COD observed in surface water range from 20 mg/L O_2 or less in unpolluted waters to greater than 200 mg/L O_2 in waters receiving effluents. Industrial wastewater may have COD levels from 100 to 60000 mg/L O_2.

In drains water samples, COD concentrations are presented in Appendix A, Table II, and are illustrated in Fig. 4.33, range between 130 mg/L in Kaliuobia drain at Eskander drain (sample No. B13) and 540 mg/L in Kaliuobia drain after Talha drain discharge, (sample No.B18). All COD values are higher than the permissible limite of law 48.(not to exceed 6 mg/L).

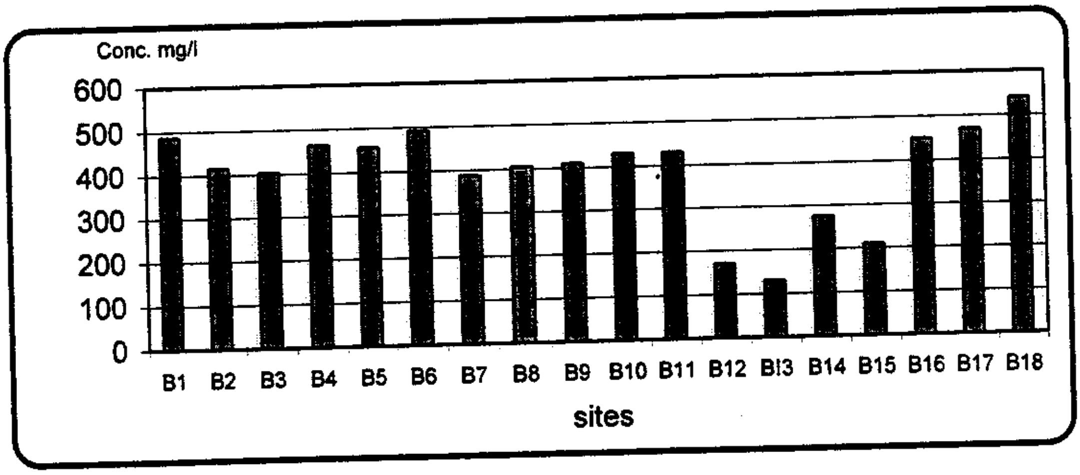


Fig.4.33, distribution of COD in the drains water samples

4.5.3 Biochemical Oxygen Demand

The biochemical oxygen demand (BOD) is an approximate measure of the amount of biochemically degradable organic matter present in a water sample. It is defined by the amount of oxygen required for the aerobic microorganisms present in the sample to oxidise the organic matter to a stable inorganic form. Unpolluted waters typically have BOD values of 2 mg/L O_2 or less, whereas those receiving wastewater may have values up to 10 mg/l O_2 or more, particularly near to the point of wastewater discharge. Raw sewage has a BOD of about 600 mg/L O_2, whereas treated sewage effluents have BOD values ranging from 20 to 100 mg/l O_2 depending on the level of treatment applied. Industrial wastes may have BOD values up to 25000 mg/l O_2 (68).

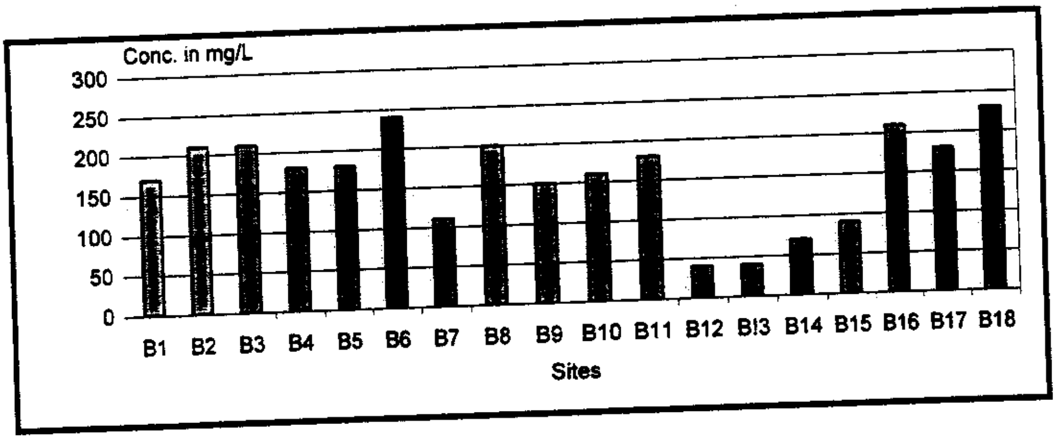


Fig.4.34, distribution of BOD in the drains water samples

In drains water samples, BOD concentrations are presented in Appendix A, Table II, and are illustrated in Fig. 3.34, range between 40 mg/L in Qaliuobia drain at Eskander drain (sample No. B12, B13), to 240 mg/L at Shebeen El-Kanater drain after Hamza drain discharge (sample No.B6). All BOD values are higher than the permissible limits of law 48 (not to exceed 6 mg/L).

The data show that COD values for drains water are higher than the BOD because the industrial effluents have poor biodegradable compounds.

4.5.4 Oil and Grease

Oil and grease enter the water bodies through domestic and industrial wastes. In surface water oil and grease accumulation kills fish and also aquatic life due to toxic effect and depletion of oxygen. Components of oils such as benzene have been found to cause cancer in laboratory animals and potentially in humans (87).

Oil and grease concentrations are presented in Appendix A, Table I, and illustrated in Fig. 3.35, for the Nile River water samples ranging between 0.11 mg/L in Ismailia canal after Abu-Zabaal fertilizer company discharge (sample No. A16), to 5.30 mg/L in Ismailia canal at discharge of El-kahera for oil refining (sample A11). All oil & grease values are higher than the permissible limits of law 48, (not to exceed 0.1 mg/L).

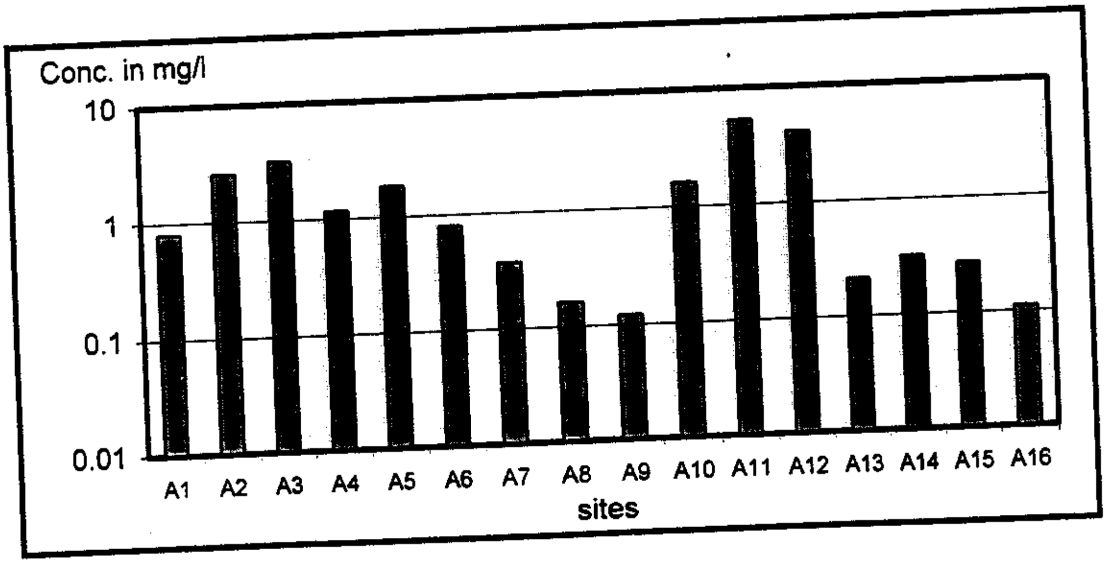


Fig.4.35, Distribution of Oil & Grease in the River Nile water samples

4.6 Removal Of Trace Metals Using Sodium Sulfide/Ferrous Sulfate.

Industrial wastes contain relatively high levels of numerous toxic trace metals in concentrations which often fail to meet permit limits of environmental pollution control laws for example law 48 (1982). Therefore, such wastewater must be treated to reduce the levels of trace metals to within discharge permit limits. The metals typically contained in this wastewater include chromium, cadmium, copper, lead, zinc, nickel and aluminum.

Lime treatment removes trace metals as insoluble hydroxides, basic salts, or copercipitated with calcium carbonate or ferric hydroxide. This process does not completely remove mercury, cadmium, or lead, so their removal is aided by addition of sulfide (most of trace metals are sulfide seekers) (24):

$$Cd^{2+} + S^{2-} \rightarrow CdS\ (s)$$

Also, metal sulfides have much lower solubilities than the corresponding metal hydroxides, thus allowing lower residual metal concentration in the treated wastewater.

4.6.1 Determination of the optimum pH

Metal precipitation by soluble sulfides requires a sulfide source more soluble than the metal to be precipitated. The solubility of the metal compounds thus formed is pH dependent; most tend to be least soluble in alkaline solutions.

Table 4.4, the results of trace metals at different pH

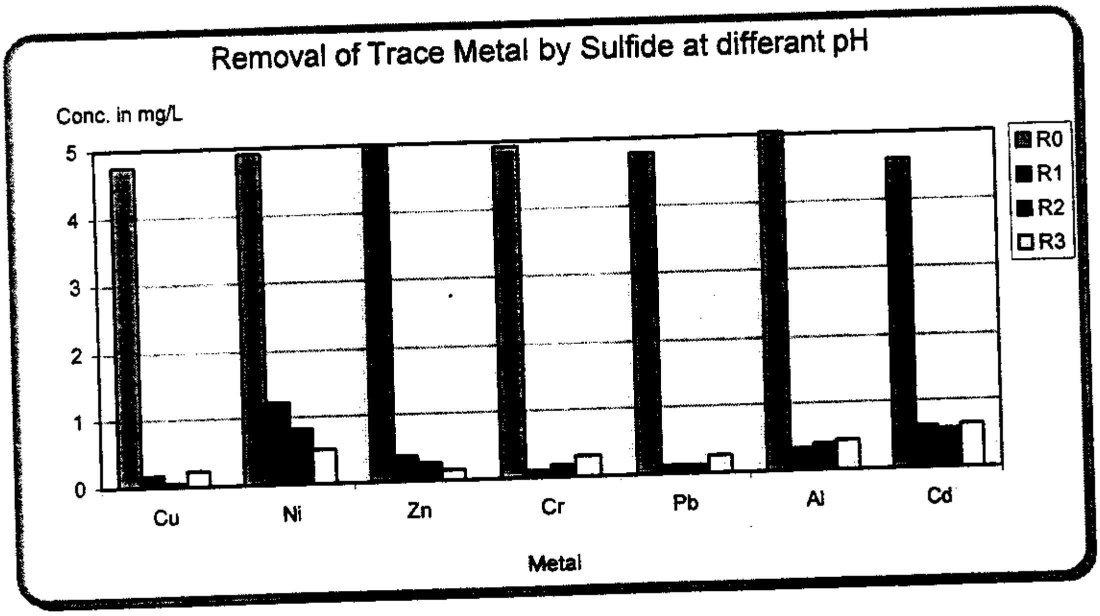
Metal	R0	R1	R2	R3
Cu	4.75	0.17	0.06	0.23
Ni	4.91	1.22	0.83	0.51
Zn	4.99	0.38	0.27	0.16
Cr	4.92	0.11	0.18	0.31
Pb	4.78	0.13	0.13	0.26
Al	5.04	0.33	0.4	0.44
Cd	4.59	0.62	0.57	0.64

Where: R0 = Metals Standard concentrations without treatment (initial pH, 4)

R1 = 5 ppm Metals: 5 ppm S^{2-}: 5 ppm Fe^{2+} at pH 7.5

R2 = 5 ppm Metals: 5 ppm S^{2-}: 5 ppm Fe^{2+} at pH 8.5

R3 = 5 ppm Metals: 5 ppm S^{2-}: 5 ppm Fe^{2+} at pH 9.5



Fig, 4.36, the optimum pH for trace metal precipitation by sulfide

The results presented in Table 4.4, and illustrated by Fig. 4.36, showed that, trace metals can be removed by precipitation as sulfides through the addition of sodium sulfide to very low concentrations under alkaline condition. Optimum pH, which gives higher metal removal, was 7.5 for Chromium and Aluminum, 8.5 for Copper, Cadmium and lead, 9.5 for Nickel and Zinc. It was noticed that at pH 9.5 a black precipitate is formed.

Since the optimal pH for precipitation depends both on the metal to be removed and on the counter ion used (sulfide). The best treatment procedure must be determined on a case-by-case basis.

4.6.2 Determination of the optimum addition of S^{2-}& Fe^{2+}:

In sulfide precipitation, once the optimal pH for precipitation is established, the settling process is often accelerated by the addition of ferrous sulfate which is a very strong reducing agent in neutral to basic conditions and is often used to reduce copper and nickel from solution. And also, used to reduce the residual sulfide concentration and provide a co-precipitant to enhance floc formation, improve settling and filtration of the sulfide precipitant.

The results data presented in table 4.5, and illustrated by Fig. 4.37, showed that, high concentrations of sulfide were shown to be more efficient in removal of trace metals than lower concentrations, even at relatively low ferrous concentrations. It was noticed that the addition of 5 ppm of metals to 10 ppm of sulfide, results in blacking the water even after filtration.

Table 4.5, Removal of metals with different concentrations of S^{2-} & Fe^{2+} at pH 8.5

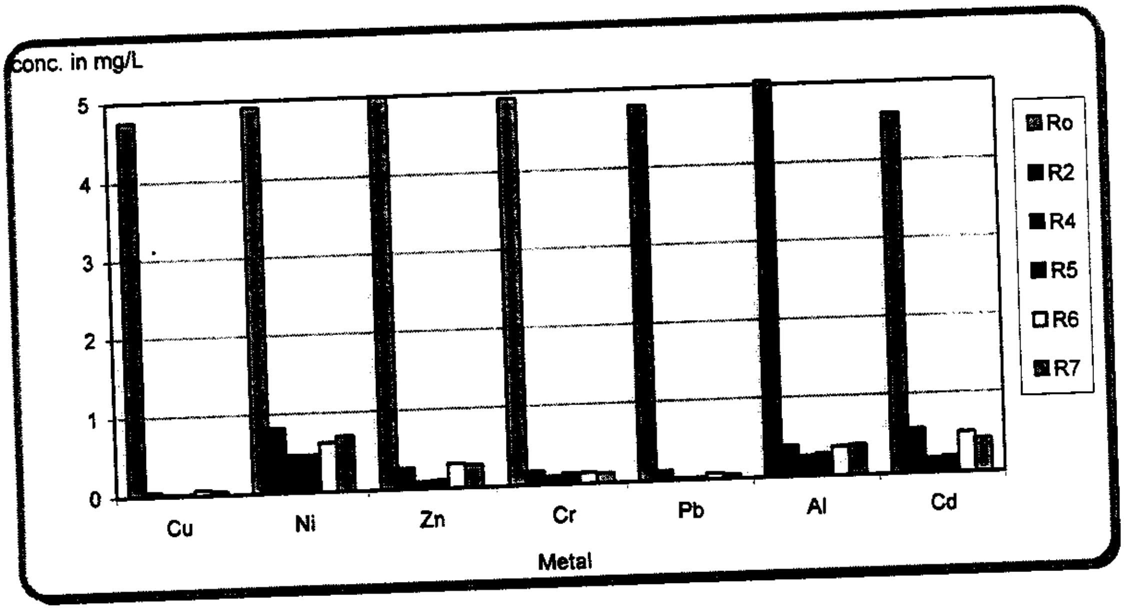
Metal	Ro	R2	R4	R5	R6
Cu	4.75	0.06	0.02	0.02	0.07
Ni	4.91	0.83	0.48	0.48	0.63
Zn	4.99	0.27	0.09	0.11	0.31
Cr	4.92	0.18	0.11	0.14	0.14
Pb	4.78	0.13	0.03	0.03	0.08
Al	5.04	0.4	0.26	0.29	0.37
Cd	4.59	0.57	0.19	0.21	0.51

Where: R4 = 5 ppm of metals: 7.5 ppm of S^{2-}: 5 ppm of Fe^{2+} at pH = 8.5

R5 = 5 ppm of metals: 10 ppm of S^{2-} : 5 ppm of Fe^{2+} at pH = 8.5

R6 = 5 ppm of metals: 5 ppm of S^{2-} : 7.5 ppm of Fe^{2+} at pH = 8.5

R7 = 5 ppm of metals: 5 ppm of S^{2-} : 10 ppm of Fe^{2+} at pH = 8.5



Fig, 4.37, Removal of trace metals at different sulfide and ferrous ratio

4.6.3 Wastewater Treatment using Sodium Sulfide & Ferrous Sulfate:

The results of trace metals analysis of water samples, are discussed in the section 4.4 The results showed that the concentrations of trace metals (Cd, Pb, Al, Ni and Cr) were higher than the maximum recommended limits of Egyptian standards (Law 48/1982), particularly in industrial wastes discharge of Kaha military factory (B14), at Mostorod drain (B2) and El-Kahera for oil refining company (A11). While Cu, Zn, and Fe were found in concentrations less than the permissible limits. Sulfide precipitation used to treat these wastes

From the results presented in Appendix C, and illustrated by Fig. 4.38, Fig, 4.39, and Fig, 4.40, sulfide precipitation has shown to be able to remove trace metals from actual industrial wastewater to values below the standards limit of Law 48/1982.

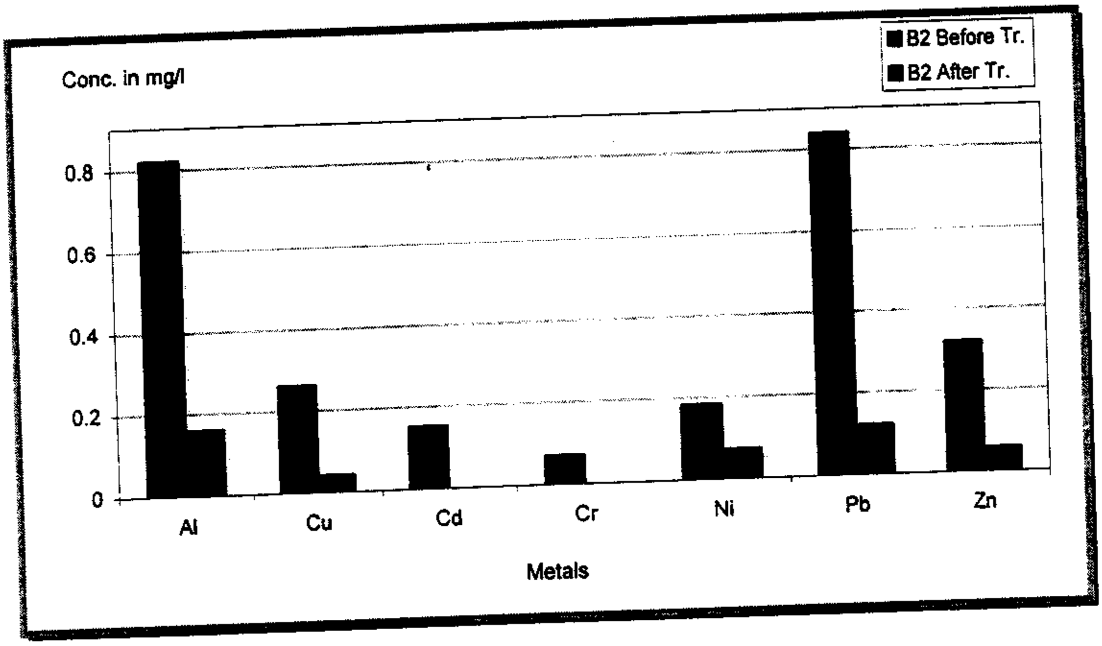


Fig. 4.38, Removal of metals from industrial drain.

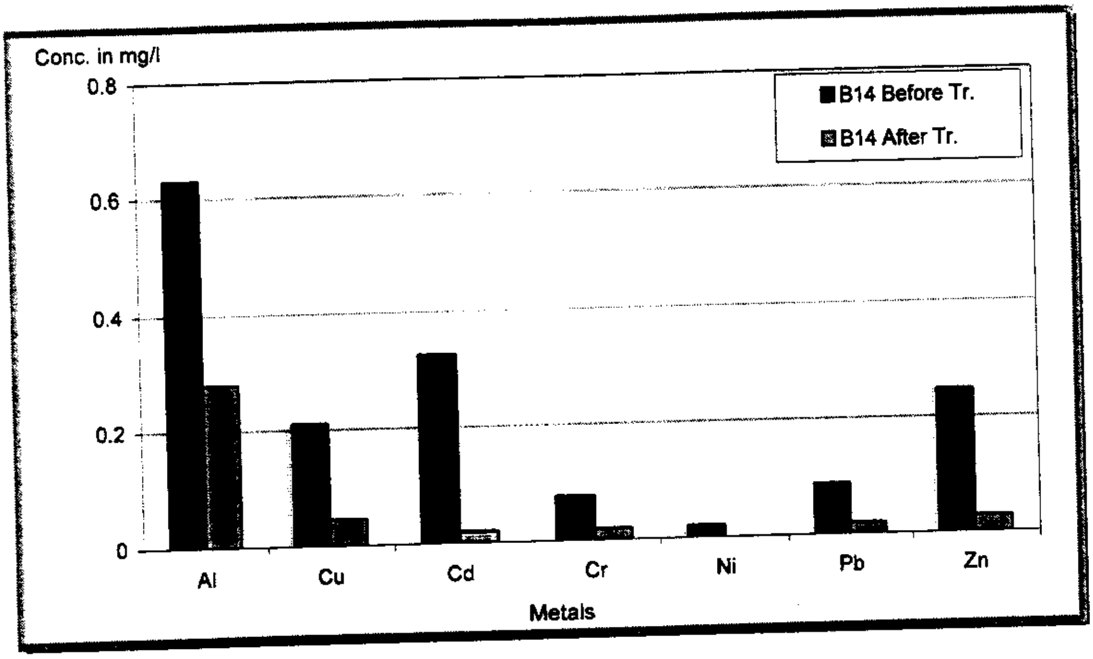


Fig. 4.39, Removal of metals from wastewater of Kaha factory

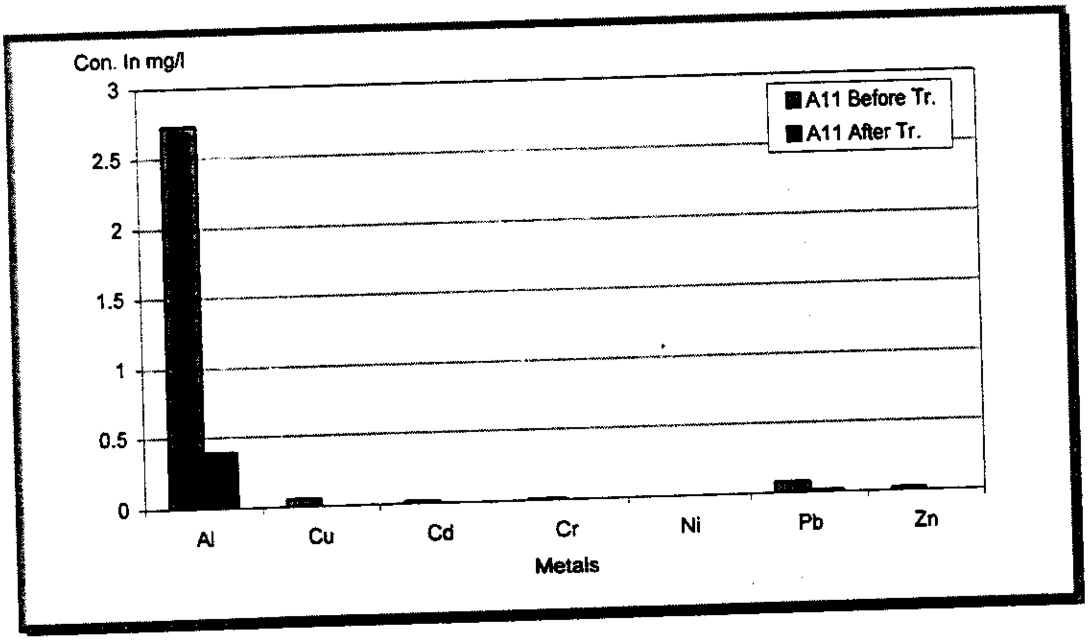
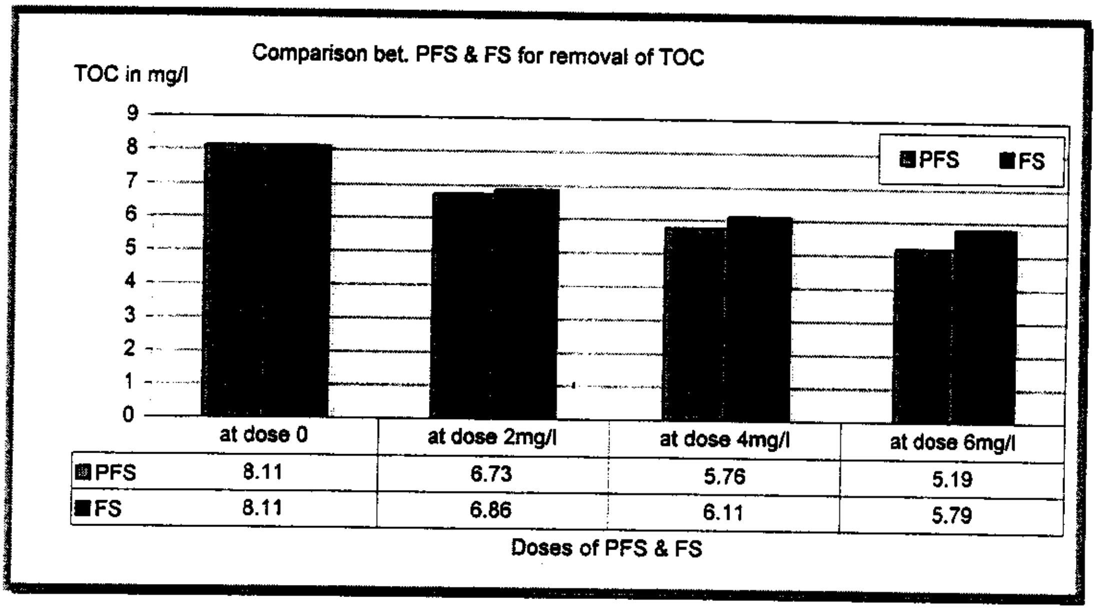


Fig. 4.40, Removal of metals from wastewater of Oil refining company

4.7 Comparison between Polyferric Sulfate and Ferrous Sulfate for removal of TOC

A recent development in water treatment has been the preparation and use of (polymeric) Fe (III) and Al species as coagulants. A process for preparing a polymeric form of ferric sulfate, wherein, an acidic aqueous solution in an oxidation stage at ambient pressure and in the absence of oxidation catalyst using at least one oxidizing agent. The polyferric sulfate obtained can be used as a coagulant or flocculant in water treatments for decolorizing; purifying or reducing pollutants with improved performance compared to conventional ferric sulfate and ferrous sulfate treatments (61).



	at dose 0	at dose 2mg/l	at dose 4mg/l	at dose 6mg/l
▨PFS	8.11	6.73	5.76	5.19
■FS	8.11	6.86	6.11	5.79

Fig. 4.41, Comparison between PFS & FS for removal of TOC